Chemical Engineering Progress

June 1954

	1	316 S. S.	Male Flange 1" 150# Tongue & Groove Facing		T & G Flg.	4 #	15.00	15.00
	1	316 S. S.	Flat Bar 1/4" x 1-1/2" x 96"		Baffles	11 #	.88	9.00
	8	316 S. S.	Hex Bolts & Nuts 3/8" x 1"		B & N	1 #		2.00
	1	316 S. S.	Tube [illegible]1/2" x 8"		Nozzle	1 #		4.00
	1	316 S. S.	Male Flange 1-1/2" S[illegible]c. Tongue & Groove		T & G Flg.	6 #	10.00	10.00
	[illegible]	[illegible]	[illegible] 24- [illegible]		[illegible]	[illegible]		50.00
	1	Steel	Plate 1/4" x 21" x 82"	Roll	Shell	135 #		[illegible]00
	1	Steel	Plate 1/4" x 32" x 32"	Cut. & Form	Head	72 #		8.00
	1	Steel	Bar 1" x 1" x 96" lg.	Roll	Jacket Ring	30 #		3.00
	1	Steel	Flat Bar 1/4" x 3/4" x 72"	Roll	Spiral	4 #		2.00
	1	Steel	Pipe 2" S.h. 40 x 4" lg.		[illegible]			1.00
	1	Steel	Elbow 1-1/2" I P S 90°		Elbow			2.00
	1	Steel	Coupling 1/2" 3000#		Coup.	1 #		1.00
	1	Steel	Welding Neck Flange 2" 150# R. F.		Flange	6 #		5.00
	1	Steel	Welding Neck Flange 1-1/2" 150# R. F.		Flange	64 #		5.00
	1	Steel	Flange 12" 150# Slip-On R. F.		Flange	61 #		30.00
	1	Steel	Pipe 1-1/2" x 6"		Nozzle	1 #		1.00
	28	Steel	Bolts & Nuts 3/4" x 5-1/2"		B & N	25 #		24.00
	1	Steel	Pipe 1-1/2" x 32'-0"		Legs	87 #		8.00
	4	Steel	Couplings 1-1/2" 3000#		Coup.	4 #		6.00
	1	Steel	Angle 4" x 4" x 1/4" x 24"		Foot pads	14 #		2.00
	2	Asbestos	Gasket 1/8" x 27-1/[illegible]					4.00
	1	316 S. S.	Tube 1/2" x 16 ga. [illegible]					5.00
			Form Heads: Stainl[illegible]					111.00
1.	1	316 S. S.	Plate 1/4" x 24" x [illegible]				.80	106.00
2.	1	316 S. S.	Plate 1/4" x 30" x [illegible]				1.07	139.00
3.	1	316 S. S.	Plate 3/16" x 4" x [illegible]				.88	8.00
4.	1	316 S. S.	Plate 1-3/4" x 8" x [illegible]				.89	30.00
5.	1	316 S. S.	Pipe 2" x 8"				11.16/1	10.00
6.	1	316 S. S.	Pipe 3" S.h. 40 x 8				22.06/1	12.00
7.	1	316 S. S.	Plate 5/16" x 18" x				.89	27.00
8.	1	316 S. S.	Pipe 3/4" S.h. 40 x				4.21/1	5.90
9.	1	316 S. S.	Male Flange 2-1/2"				20.00	20.00
10.	1	316 S. S.	Male Flange 3" 150				35.00	35.00
11.	1	316 S. S.	Male Flange 1" 150#				15.00	15.00
12.	1	316 S. S.	Flat Bar 1/4" x 1-1				.88	9.00
13.	8	316 S. S.	Hex Bolts & Nuts 3/					2.00
14.	1	316 S. S.	Tube 1-1/2" x 9"					4.00
15.	1	316 S. S.	Male Flange 1-1/2"				20.00	20.00
16.	2	Steel	Forged Rings 29" O					150.00
17.	1	Steel	Plate 1/4" x 21" x 8					14.00
18.	1	Steel	Plate 1/4" x 32" x					8.00
19.	1	Steel	Bar 1" x 1" x 96" lg					3.00
20.	1	Steel	Flat Bar 1/4" x 3/4" x 72"	Roll	Spiral	4 #		2.00
21.	1	Steel	Pipe 2" S.h. 40 x 4" lg.		Nozzle	2 #		1.00
22.	1	Steel	Elbow 1-1/2" I P S 90°		Elbow	1 #		2.00
23.	1				Coup.	1 #		1.00
24.	1				Flange	6 #		5.00
25.	1				Flange	64 #		5.00
26.	1				Flange	61 #		30.00
27.	1				Nozzle	1 #		1.00
28.	28				B & N	25 #		24.00
29.	1				Legs	87 #		8.00
30.	4				Coup.	4 #		6.00
31.	1	Steel	Angle 4" x 4" x 1/4" x 24"		Foot pads	14 #		2.00
32.	2	Asbestos	Gasket 1/8" x 27-1/4" O D x 24" I D		Gasket	1 #		4.00
33.	1	316 S. S.	Tube 1/2" x 16 ga. wall x 39" lg.		Tube	1 #		5.00
			Form Heads: Stainless $90.00 - Steel $21.00					111.00
			Total			1140 #		824.00

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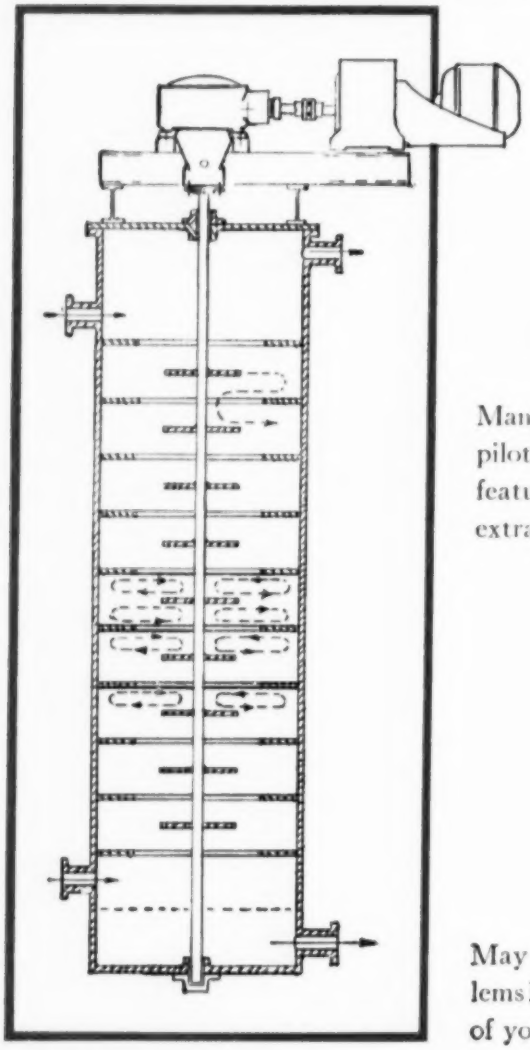
GENERAL AMERICAN TRANSPORTATION CORPORATION



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Rotary Disc Contactor for Liquid-Liquid Counter-current Extraction

Many years of data and design development in the laboratory, pilot plants and industry have demonstrated the superior features of this practical counter-current and gravity flow extractor. The R. D. C. extractor offers:

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2. **high throughput capacity**
3. **simplicity of construction**
4. **no interstage or external settlers**
5. **low power requirements**
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LETTERS TO THE EDITOR

Simple and Clear

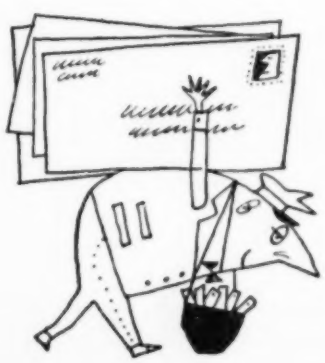
I have been following with great interest Dr. H. J. Tichy's articles "Engineers Can Write Better." It is encouraging that people are finally waking up to the indisputable fact that technical writing has been, in general, a pretty sorry affair.

I am rather flattered that in his second article Dr. Tichy has used so much space to discuss a portion of my short article "A Plea for Simplicity," which appeared in C.E.P. for November, 1952. But I get the feeling that the professor is speeding in two opposite directions at the same time. He devotes five paragraphs to a diatribe against simplification—calls it a "shocking, stupid waste" of engineers' time. But only a few paragraphs later he takes my simplification of sentence and himself simplifies it still further (and does a good job too). Then he recommends that the engineer practice and devote time and effort to writing the way he (Dr. Tichy) does. What is this but simplification? Which side of the fence is the professor on, anyway?

As a matter of fact, and although Dr. Tichy would probably deny this vehemently, I believe he and I are aiming at somewhat the same ultimate goal for technical writing. My article wound up ". . . . you will be able to express your thoughts easily, simply, and understandably." The professor says ". . . his (the engineer's) speaking and writing will be smoother, easier, and clearer." One of Mr. Webster's synonyms for *simplicity* is *clearness*.

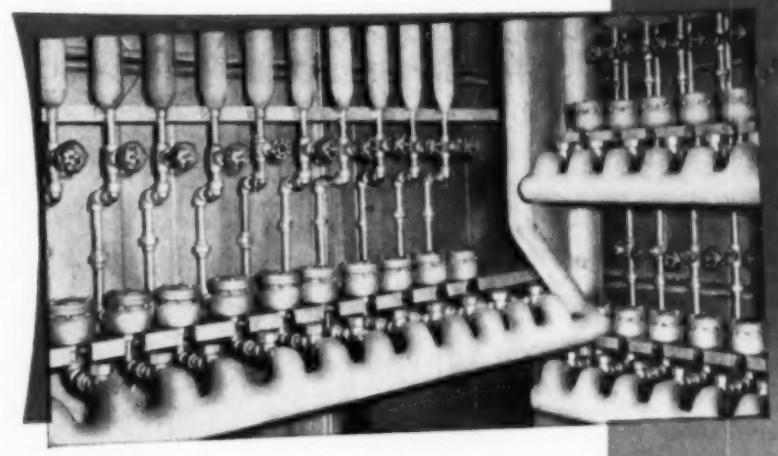
There are two points, though, where Dr. Tichy and I must part company. For example, he says, "The man who insists that complex scientific material be simplified . . . cannot grasp complex ideas, fine distinctions in meaning, adult thinking." Ridiculous! Just because a man has a good

(*Continued on page* 10)



NICHOLSON TRAPS SELECTED

for Armour Chemical Plant



Above, new McCook, Ill., plant of Armour and Company's Chemical Division. Nicholson steam traps were specified throughout. Left above, a battery shown on tracer lines warming fatty acids.

Many chemicals are made available in commercial quantities for the first time by this new Armour Chemical Division plant. With demands for process steam alone as high as 80,000 pounds per hour, the entire plant is equipped with Nicholson steam traps, both grounds and buildings.

Features of Nicholson thermostatic steam traps: 2 to 6 times average drainage capacity; shorten heat-up time. Operate at lower temperature differential; fast action keeps equipment full of live steam. Maximum air-venting capacity. Freeze-proof. Types for every process, power, heat application.

Send for NICHOLSON TRAP CATALOG 953

Catalog 953 contains capacity tables, installation diagrams, and data, charts and formulae for determining the proper size trap.

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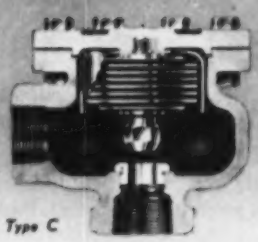
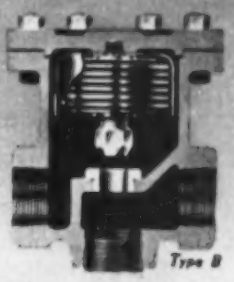
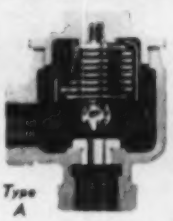
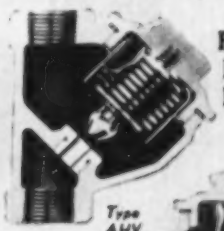


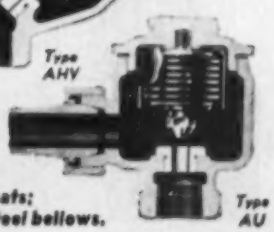


The two types above are semi-steel; sizes ½" to 2"; pressures from vacuum to 250 lbs. Type C also in cast steel for pressures to 300 lbs.

FIVE TYPES FOR EVERY PLANT USE







These three types are bronze; sizes ¼" to 1"; pressures from vacuum to 200 lbs. All 5 types have stainless steel valves and seats; bronze, monel or stainless steel bellows.

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IMPERVIOUS GRAPHITE PROCESS EQUIPMENT

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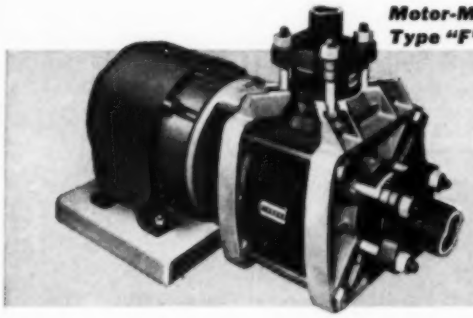
NATIONAL CARBON offers from stock a complete line of "Karbate" Heat Exchangers including 2 shell and tube units: "Series 90A" and the "Series 310A". Now—"Karbate" "Series 310A" Heat Exchangers are available with a choice of 9, 12, 14 or 16 foot tube lengths, having outside tube surface areas up to 162 square feet, providing a greater range of sizes and flexibility of application at lower costs per unit of area. Larger sizes with up to 2,300 sq. ft. of tube-surface area per unit are sold by leading heat exchanger manufacturers. An extensive standardization of the "Karbate" tube bundles and covers for these sizes assures low first cost with faster delivery.

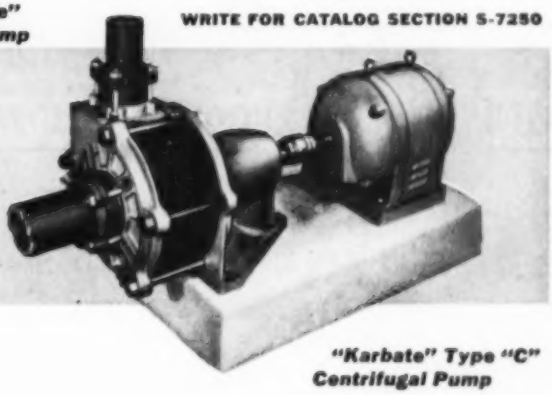
WRITE FOR CATALOG SECTION S-6740

FEATURING improved designs in a broad range of capacities, "Karbate" pumps are your best buy for the widest span of corrosive fluids, including even mildly corrosive services. Ruggedly built, these new pumps are meeting the toughest requirements, virtually eliminating pump down-time.

Motor-Mounted "Karbate" Type "F" Centrifugal Pump



WRITE FOR CATALOG SECTION S-7250



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LETTERS TO THE EDITOR

(Continued from page 4)

set of teeth, does he insist on eating the toughest meat he can buy?

The other point is really part of the same philosophy. Throughout Dr. Tichy's articles runs an attitude of "We're writing for a select group, boys—let's make sure the riffraff doesn't understand what we say." If this is our creed, Heaven help the engineers! We're far too misunderstood already. But even if our writings are never read by anyone but other engineers, we still owe it to our readers to write as simply and clearly as we know how. I've never yet heard a man say "This article is too understandable." But almost every day I hear "What in censored is this guy driving at?" And this from readers who, despite Dr. Tichy's opinion, are "educated, intelligent adults."

HOWARD M. MATHIS

Alhambra, Calif.

Both Mr. Mathis and Dr. Tichy have the same goal—improving technical writing. We say, "More power to all laborers in *that* vineyard."

Mathis likes the sentence that results from application of Tichy's principles; Tichy does not like the three sentences that result from the application of the principles of Mathis. Tichy recommends using the vocabulary and sentence structure appropriate to the idea; Mathis insists on the use of "the simplest word that will do the job" and rewrites each example by dividing one sentence into a number of short ones.

When Mathis quotes Tichy in his fourth paragraph, he inadvertently changes the meaning by omitting important words. Tichy wrote about "the man who insists that complex scientific material be simplified for poor readers. . . ." Omitting the words "for poor readers" changes the meaning.

The amount of simplification necessary troubles every editor of a technical journal. We believe that readers can understand complex ideas in their own field, and we do not advocate artificial application of set rules to achieve simplicity.

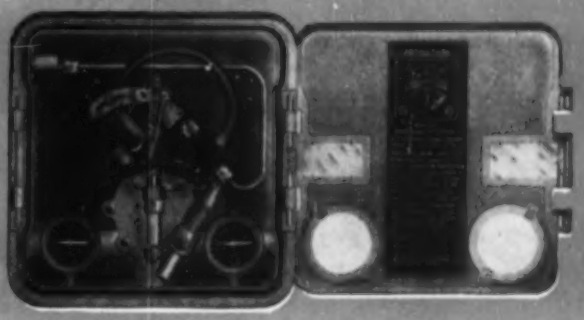
Whether Dr. Tichy considers engineers "a select group, boys" is a question the editors can not answer. We leave that to the lady herself.—*Editor.*

Excerpts from some of the many favorable comments on Dr. Tichy's series appear on page 14.

(Continued on page 14)

BS&B Announces:

. . . An Even Better Pressure Controller — Climax Type 1440



The Climax Type 1440 Pressure Controller (non-recording) is designed to handle both positive and negative pressures, from high vacuum to pressures of up to 10,000 lbs. Bourdon Tube actuated — with all tubes, bellows assemblies, feed orifices and bleed nozzles calibrated — the Type 1440 is an instrument of utmost accuracy. Proportional band and On-Off or Maximum-Minimum snap action adjustment is easily made without additional parts. Snap action may be adjusted to pressures up to 75% of the limits of the Bourdon Tube rating.

. . . An Even Better Liquid Level Controller Pilot . . . Climax Type 1450

The type 1450 Liquid Level Controller Pilot was developed for use and mounting on any Climax Type 886, 886-LF, 887 and 889 displacement liquid level controllers where a torsion tube transmits float movements to reflect changes in liquid level or a change in gravity of the controlled liquid. Its interchangeability of parts with those of the Type 1440 Pressure Controller is an advantage which reduces stocking parts.

Type 1450 features a very wide "throttling" range calibrated from 0% to 100%. A specific gravity index is provided and offers a method of compensating for various gravities of liquids, or for inter-face services, where the "throttling" range is kept exact in its relationship to the specific gravity setting.

A novel feature of the Type 1450 is its adjustability, without use of special parts, for "snap" or "on-off" action. This is useful when it becomes desirable for the diaphragm control valve to fully open or close when liquid level height reaches a desired "high" setting, and to react in an opposite manner at a desired "low" setting. The amount of liquid level change from open to shut positions of the control valve may be varied up to 75% of displacement element length.

Improved Features of Types 1440 and 1450:

1. Weatherproof case of die-cast aluminum designed for universal mounting.
2. Compact size — 8" x 8" x 4".
3. Door hinges to left or right, as desired.
4. Straight line piping.
5. Proportional bellows, calibrated, spring opposed.
6. Micro-adjusted set-point, graduated.
7. Molded diaphragms in power unit.
8. Easy parts replacement or assembly.
9. Feed orifice cleaner.
10. Snap action available over 10% to 75% of tube range without additional parts. (Applies to Type 1440 only.)
11. Pilot action reversible by moving a single link, without tools.
12. Elimination of superfluous linkages, resulting in easier adjustability and greater sensitivity.

Types 1440 and 1450 Have Been Developed and Thoroughly Field Tested for More Than Two Years!

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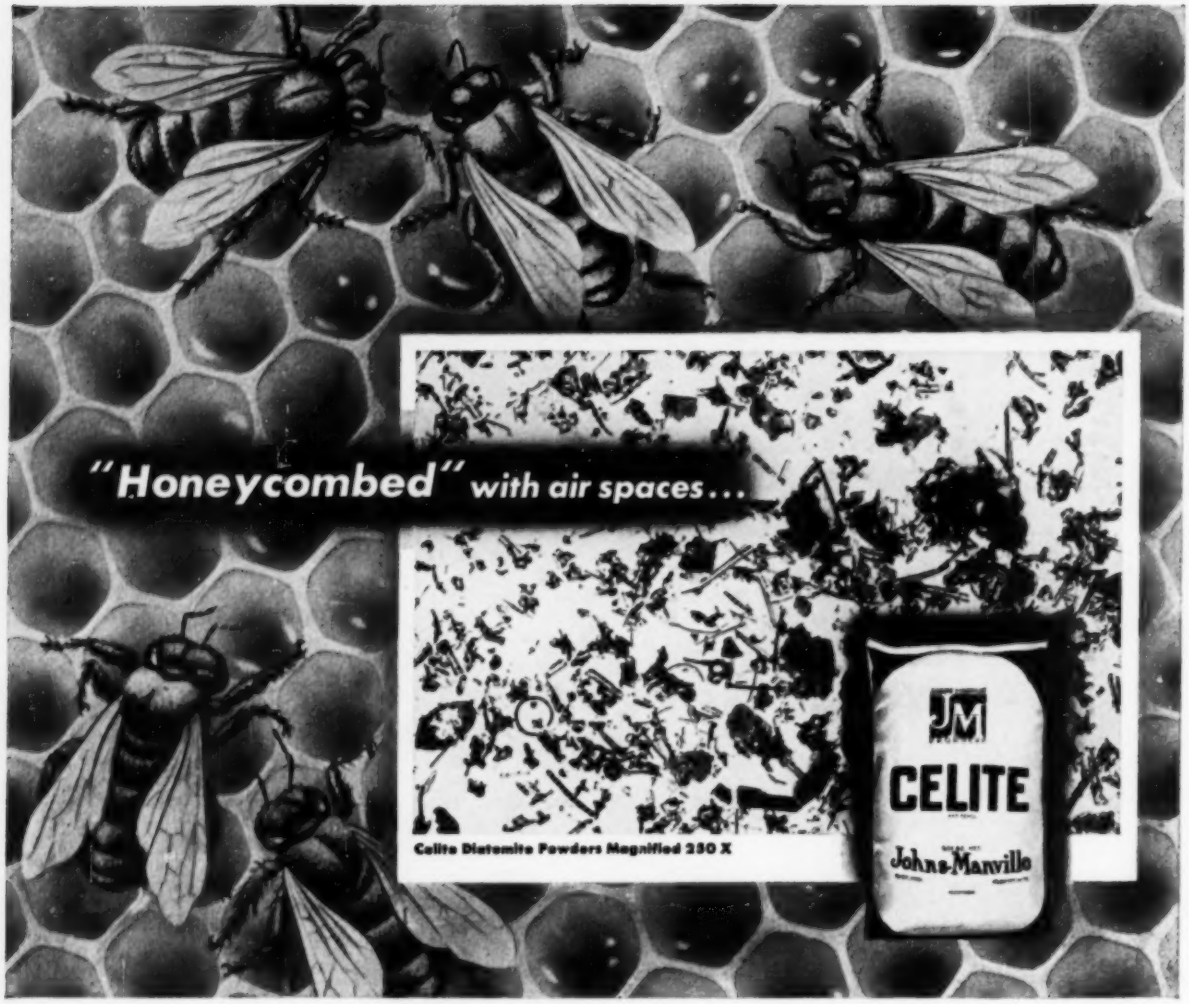

Celite Powders provide bulking action

3 to 10 times greater than any other inert mineral filler

POUND FOR POUND, Celite* diatomite powders supply more bulking action than any other inert mineral filler because their cubic volume is 3 to 10 times greater. Celite's unique "honeycombed" structure is composed of microscopic, irregularly shaped particles that won't pack down. In mass they weigh only about 10 lbs. per cubic foot.

That's why Celite is so widely used to add bulk and body to industrial formulations. For example, it extends white pigments in paints and papers . . . it improves dispersion of insecticides and fertilizers . . . it fluffs up dry powders such as household cleansers.

Also, from Celite's "honeycombed" structure comes its great absorptive capacity. This characteristic is profitably utilized to keep powders free-flowing . . . to provide a medium for shipping or storing liquids in dry form. And because of the physical structure of its individual particles, Celite has become the outstanding flatting agent for paints . . . it serves as a mild, non-scratching abrasive for fine polishes . . . it improves the surface appearance of plastics.

Which of the many Celite advantages can you use to build product performance or cut costs? A Johns-Manville Celite Engineer will gladly discuss your problem, without obligation. For his services or more information, write Johns-Manville, Box 60, New York 16, New York. In Canada, 199 Bay St., Toronto 1, Ontario.

*Celite is Johns-Manville's registered Trade Mark for its diatomaceous silica products.

JOHNS-MANVILLE JM PRODUCTS **Johns-Manville CELITE** INDUSTRY'S MOST VERSATILE MINERAL FILLER

Ammonia, formerly produced from coke, is now made from natural gas by the Nitrogen Division, Allied Chemical & Dye Corporation at its Hopewell, Virginia and South Point, Ohio plants. A third plant is now nearing completion at Omaha, Nebraska. Girdler designed and built the natural gas reforming plants at all of these locations. Girdler catalysts are used in these gas plants.

THIS IS GIRDLER

ALLIED CHEMICAL & DYE CORPORATION is "advancing America's chemical frontiers"

Allied Chemical & Dye Corporation's Nitrogen Division, one of the world's important producers of nitrogen products, is expanding its operations to produce more and better products. Girdler is helping in this program.

Girdler has designed and built three new natural gas reforming plants for Nitrogen Division. All of these units use natural gas for process material.

GIRDLER DESIGNS processes and plants
GIRDLER BUILDS processing plants
GIRDLER MANUFACTURES processing apparatus

GAS PROCESSES DIVISION:

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Lard	Chemicals	Resins
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LETTERS TO THE EDITOR

(Continued from page 10)

Your very interesting series of articles currently appearing in *Chemical Engineering Progress,* entitled "Engineers Can Write Better," bridges a considerable gap in the line of communication from engineers. In our company we have long felt the need to give our engineers some down-to-earth counseling on this subject. Your discussion provides additional ammunition for our cause, and sheds considerable light on this topic.

J. D. WILKINSON

South Pasadena, Calif.

The article "Engineers Can Write Better —Part I" is excellent. I hope the other parts will soon follow and that the series will be offered as a booklet. Such a booklet would be extremely valuable for student instruction.

CLYDE ORR, JR.

Atlanta, Ga.

I enjoyed your article. . . . You made it particularly helpful by getting down to specific illustrations of sentence errors. I am looking forward to the rest of the series.

E. B. NOEL

Cleveland, Ohio

I found your article of timely interest and value. I am eagerly looking forward to Part II. Next issue, perhaps?

PHILLIP FINEMAN

Lemont, Ill.

Apprising and Appraising

I have just read your editorial in the April issue on "The Need to Know."

You are concerned—and rightly so—that the public is not sufficiently enlightened about the destructive power of large bombs and their significance to the future. However, I feel that you are hardly justified in your intimation that the A.E.C. is derelict in not giving enough information to the public. Lewis Strauss' press conference at the White House (which probably came out after you wrote the editorial) tells enough to permit a realistic appraisal of the effects of megaton explosions.

The big unknowns today are the deliverability of such weapons and the defense against their delivery. These are problems of the Department of Defense, and information on them is necessarily quite restricted.

I suggest that the really essential information on bomb energies and blast effects is available, but that we citizens are reluctant to face up on short notice to the shocking conclusions.

WALTER G. WHITMAN

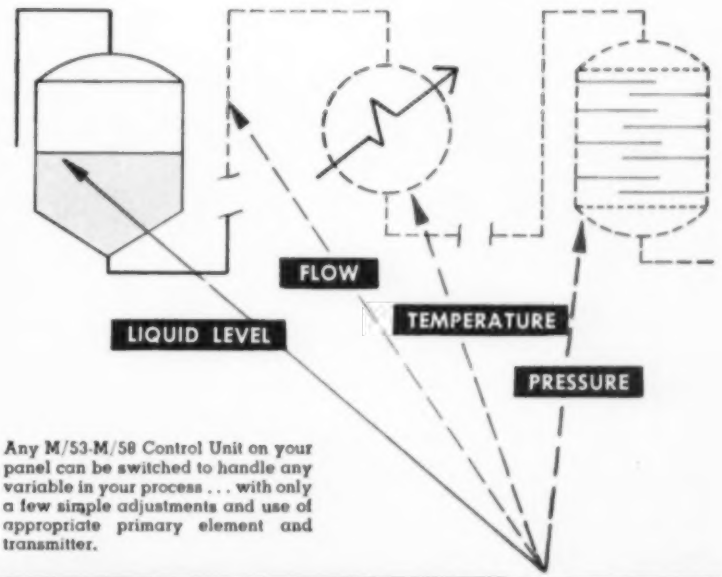
Cambridge, Mass.

No obsolescence for this controller when process requirements change!

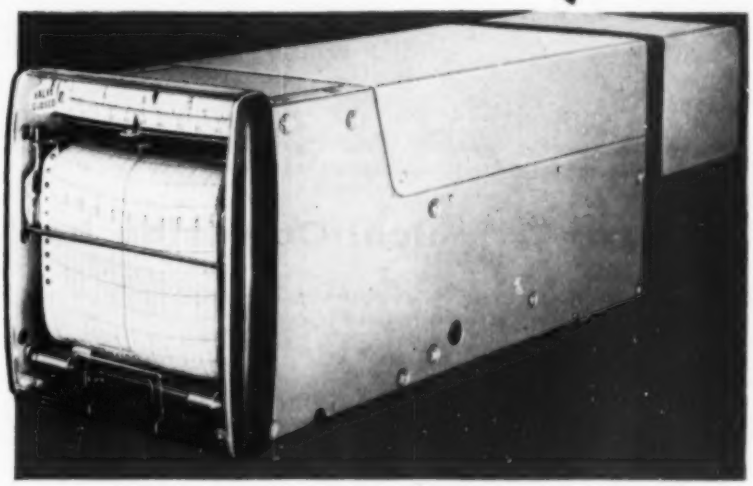
That's right! The Foxboro M/53-M/58 Recorder-Controller is a "universal" instrument, equally adaptable to any process measurement — whether flow, temperature, pressure, liquid level, or other.

All it takes is connection to the proper measurement transmitter having a 3-15 psi pneumatic signal . . . and making the appropriate controller settings. Changes such as adding derivative to reset or proportional control can be made *on the job* without special tools or realignments. You save needless duplication in capital investment . . . save time and trouble in making process revamps . . . and get the unsurpassed performance of M/58 control on every application!

Whether you favor graphic, console, or conventional mounting, you can cut instrument overhead at every stage, step-up efficiency in every operation, with the Foxboro M/53-M/58 Recorder-Controller. Write for complete information. **The Foxboro Company, 936 Neponset Ave., Foxboro, Mass., U.S.A.**



Any M/53-M/58 Control Unit on your panel can be switched to handle any variable in your process . . . with only a few simple adjustments and use of appropriate primary element and transmitter.



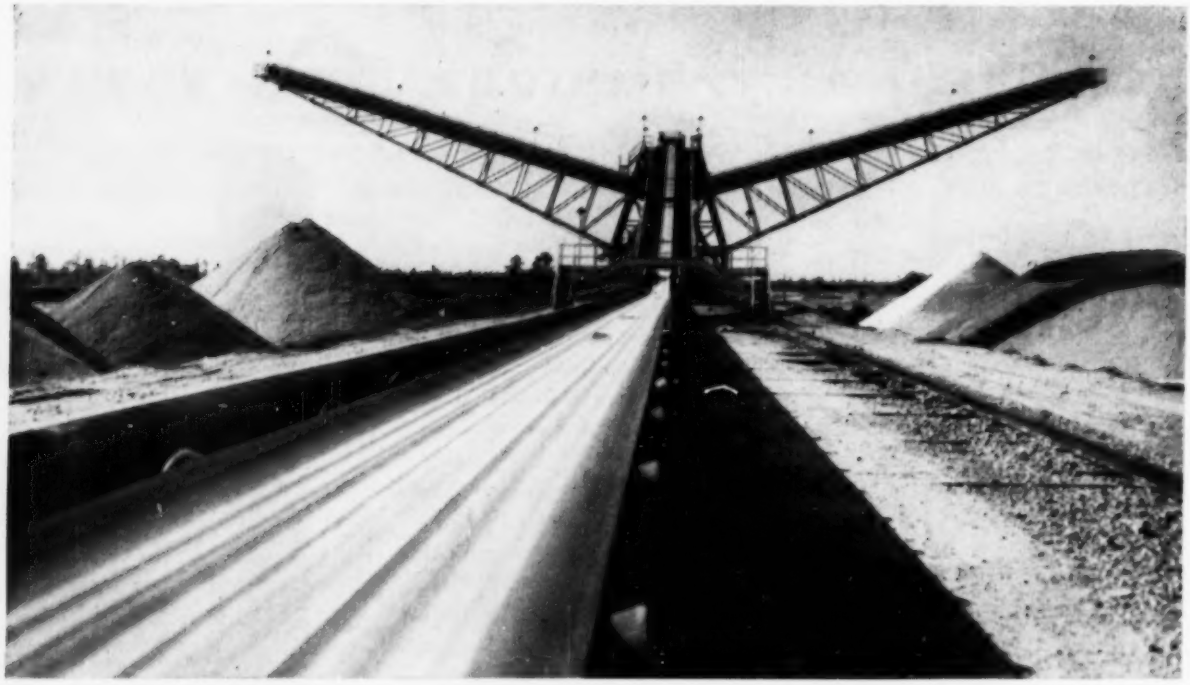
OTHER BASIC ECONOMIES

- **Simplified Ordering**
  —complex specification sheets are eliminated.
- **Reduced Stock Inventory**
  —only one type recorder-controller for all control jobs.
- **Reduced Maintenance**
  —fewest parts, rugged design, no diaphragms, highest quality throughout.

FOXBORO
REG. U.S. PAT. OFF.

Consotrol Process Control

FACTORIES IN THE UNITED STATES, CANADA AND ENGLAND



Stockpiles Phosphate Rock 7 Stories High—and Keeps Handling Costs at Rock Bottom

Stacker discharges 1088 foot center trunk line belt conveyor to either side. Rock is piled at a rate of 635 long tons per hour.

This giant traveling stacker has a "wingspread" of 220 feet and stands taller than a 7 story building. Engineered by S-A for the Virginia-Carolina Chemical Company's plant at Nichols, Florida, it stockpiles huge quantities of phosphate rock for drying prior to final moisture removal in a huge kiln. Rock moves from storage to the kiln via a tunnel belt conveyor system.

The phosphate rock is fed to the stacker wing conveyors by a 36-inch trunk line belt conveyor running on 1088 foot centers along the storage area. Rock flows to either of the two wing conveyors extending from the stacker tower at a rate of 635 long tons per hour. Rail clamps permit stationary operation of the stacker which forms piles about 90 feet high.

S-A "Simplex" carriers with spun end rollers turning on roller bearings protected by labyrinth seals are used on both trunk and boom belts. Other design features include S-A Hold-Backs which prevent belt reversal in case of power failure and Spring Type Belt Wipers which insure a clean belt surface in contact with the return rollers.

While a stacker piling rock 90 feet high may be beyond your needs, the same S-A engineering and manufacturing skill is available for your own specific problems—to help *you* handle *your* product at lowest cost per ton, using whatever type of bulk material handling equipment is best for you. Write, without obligation, for a free survey.

STEPHENS-ADAMSON MFG. CO.

57 Ridgeway Ave., Aurora, Ill. • Los Angeles, Calif. • Belleville, Ont.

Engineering Division
Specialists in the design and manufacture of all types of bulk materials conveying systems.

Standard Products Division
A complete line of conveyor accessories including centrifugal loaders—car pullers—bin level controls—etc.

SealMaster Division
A complete line of industrial ball bearing units available in both standard and special housings.

HOW QUICK CAN YOU CLOSE A VALVE?

That depends on the size and type of valve, of course. But with a Rockwell-Nordstrom valve it's only a quarter-turn eased by a film of lubricant.

Another thing—with simple maintenance a Nordstrom valve will never stick or leak in an emergency. The same lubricant that makes turning easy is also a hydraulic jack to free the plug, and at the same time is a leak-closing pressure seal around the valve ports.

Specify the original lubricant seal valve. There's no substitute for Rockwell experience—use it to save money on valves. *Rockwell Manufacturing Co., Pittsburgh 8, Pa.*

THREE WAYS THE NORDSTROM LUBRICANT WORKS

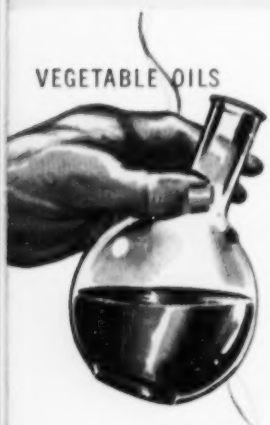
1. Lubricant surrounds each valve port with a vapor tight pressurized seal. **Nordstrom valves stay tight.**
2. Lubricant acts as hydraulic jack—a fast quarter-turn to open or close. **Nordstrom valves operate quickly.**
3. Lubricant coats the plug for sliding action—no wear-producing wedging. **Nordstrom valves operate easily.**

Rockwell Built

NORDSTROM VALVES

Lubricant-Sealed for Positive Shut-Off

WHAT DO THESE LIQUIDS HAVE IN COMMON?

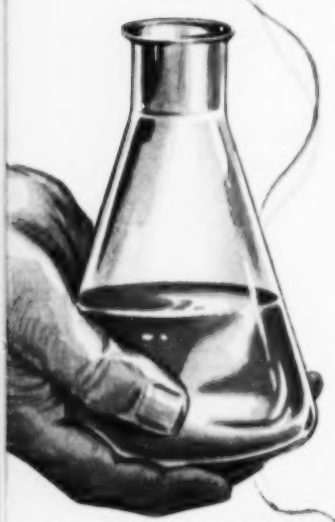


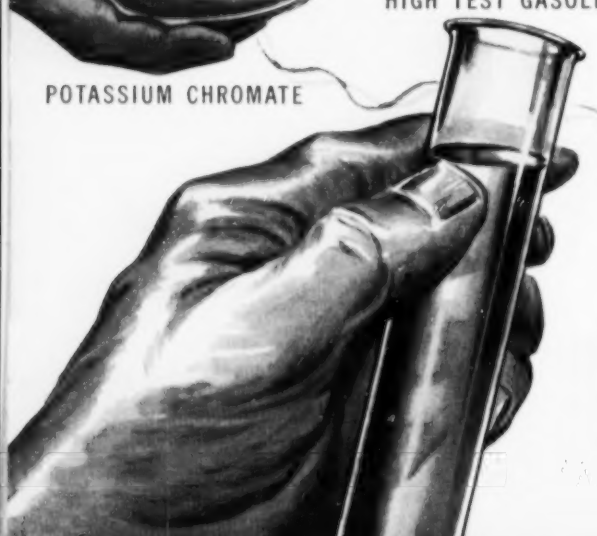
They differ widely in viscosity, volatility and other physical characteristics . . . Yet they are all successfully controlled by Rockwell-Nordstrom lubricant-sealed valves.

Nordstrom adaptability for all these—and hundreds of other—difficult liquid services lies in the basic Nordstrom design. The system of internal valve grooving, patented by Nordstrom, distributes lubricant around the valve ports for a pressure-tight seal. The same lubricant gives a bearing surface for easy operation, prevents the grinding wear of metal-to-metal contact, and acts as a hydraulic jack.

Nordstrom is the first and by far the most complete line of lubricated plug valves. Rockwell engineers can help you fit the right valve and the correct, tested genuine Nordstrom lubricant to your process.

Rockwell Manufacturing Company, Pittsburgh 8, Pa.





Nordstrom Valves

Another Quality ROCKWELL Product

Chlorine...

for the Petrochemical Industry

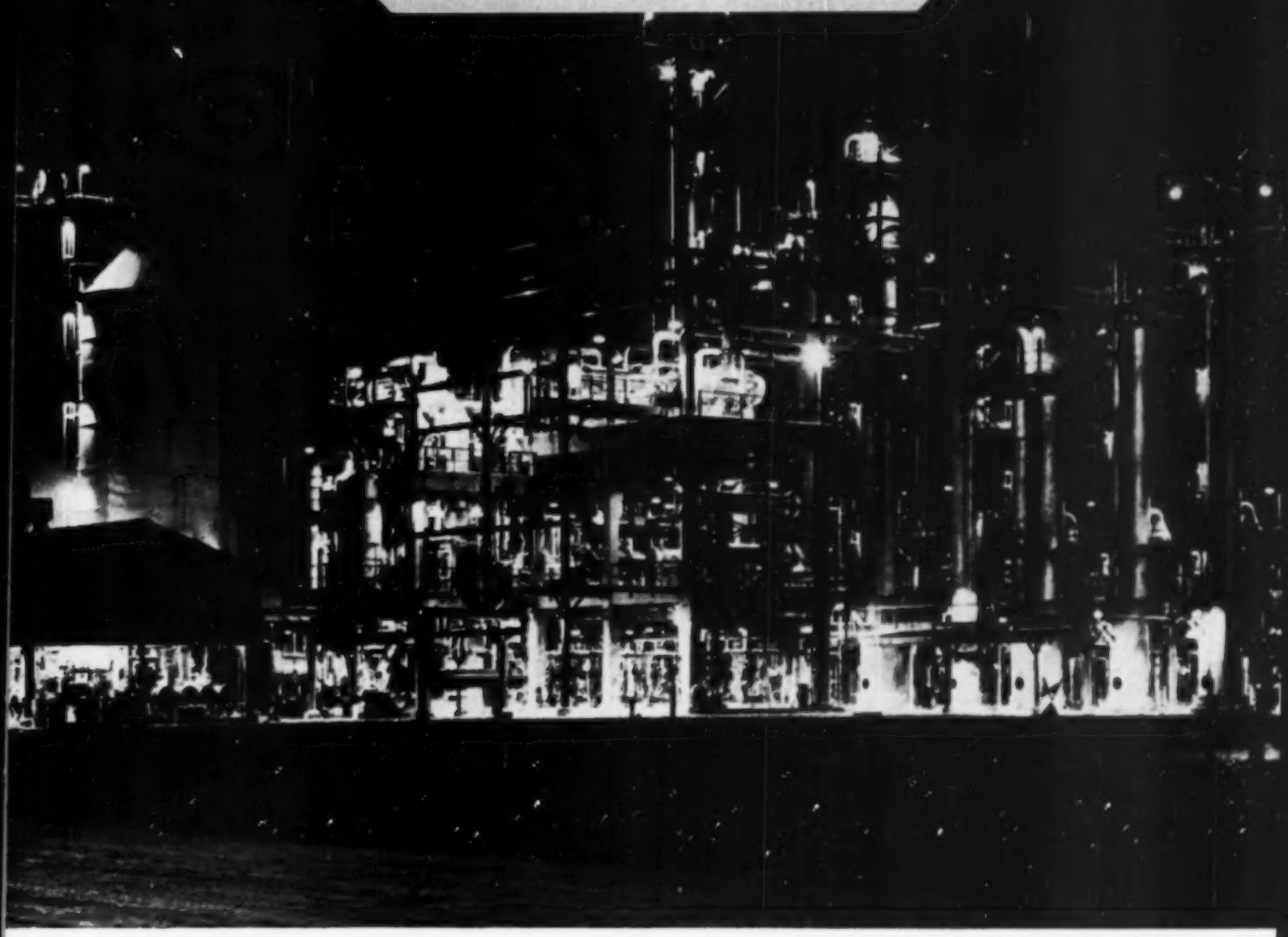
Chlorine is of swiftly growing importance in the production of many new and revolutionary petrochemicals.

Swiftly growing, too, is the use of uniformly high quality GLC GRAPHITE ANODES—in helping the electrolytic industry meet the increasing civilian and defense needs for chlorine and caustic soda.

ELECTRODE DIVISION

Great Lakes Carbon Corporation

Niagara Falls, N.Y. GLC® Morganton, N. C.



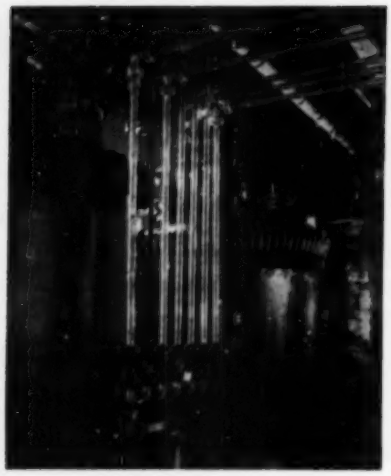
Courtesy Jefferson Chemical Company Inc.

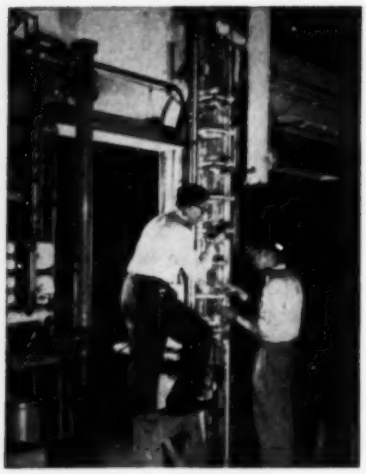
Graphite Anodes, Electrodes, Molds and Specialties

Sales office: Niagara Falls, N.Y. **Other offices:** New York, N.Y., Oak Park, Ill., Pittsburgh, Pa.

Sales Agents: J. B. Hayes, Birmingham, Ala.; George O'Hara, Long Beach, Cal.; Great Northern Carbon & Chemical Co., Ltd., Montreal, Canada

Overseas Carbon & Coke Company, Inc., Geneva, Switzerland; Great Eastern Carbon & Chemical Co., Inc., Chiyoda-Ku, Tokyo





For Left: **PYREX brand "Double-Tough" Glass Pipe** ends replacement of corroded lines... simplifies cleaning . . . enables you to *see* what's happening inside the line.

Available in 1" to 6" I. D. with all standard fittings, as well as sink traps. Your plant personnel can handle PYREX pipe without special training.

For information and pictures, check the coupon below for "PYREX brand Glass Pipe in the Process Industries" (EA-1) and "PYREX brand 'Double-Tough' Glass Pipe and Fittings" (EA-3).

Left: **PYREX brand Fractionating Columns** give you unusual advantages in solving fractionating and absorption problems. No corrosion, no contamination. And you *see* flow, performance and condition of product.

Available in 4" and 6" sizes with any number of plates.

Standard packed columns are available in 4", 6", 12" and 18" inside diameter sizes. Can be packed with PYREX brand Glass Rachig Rings. Check the coupon for data sheet of helpful information and applications.

Have YOU a corrosion problem one of these glass products can cure?

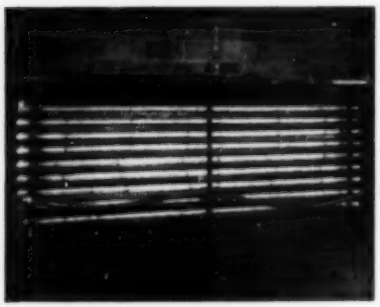
Corrosive liquids create special problems. Your pipes, coolers, and fractionating columns forever need attention, repairs or replacement. Product contamination is common. There's no fast, sure method of cleaning corroded equipment.

Why put up with these headaches when you can easily avoid them with PYREX brand glass equipment?

These are reasons why glass takes the headaches out of corrosive liquids:

1. *Glass does not rust* . . . It's unaffected by all *acidic* solutions and acids except hydrofluoric.
2. *Glass is non-contaminating* . . . The high chemical stability of PYREX brand glass equipment assures product purity.
3. *Glass is transparent* . . . You see what's happening as it happens. You have an immediate visual check on conditions within the equipment.
4. *Glass is easy to clean* . . . There's no place for deposits to build up on its hard, smooth surface.
5. *Glass is strong* . . . PYREX brand glass No. 7740, used for pipe, cascade coolers, and towers, has great physical and thermal shock resistance.
6. *Glass is economical* . . . Installation is simple. Maintenance is negligible. You will find the initial and maintenance costs of PYREX equipment low.

It will cost you nothing to find out if PYREX brand glass equipment can help you. And finding out may bring important savings. *Write, wire, or phone the nearest Corning plant equipment distributor listed below. Or mail the coupon.*



Above: **PYREX brand Cascade Coolers** give you low cost per BTU transferred, *plus* low cost operation. As many as 40 tubes can be stacked vertically in a single unit (20 tubes under one trough) to meet varied requirements. You can use cheap river or sea water as the coolant.

Check illustrated bulletin (PE-8) on the coupon for complete information on PYREX brand Cascade Coolers. It demonstrates why PYREX tubes provide high heat transfer.

DISTRIBUTOR LIST

BELMONT, CALIFORNIA	Glass Engineering Laboratories
FRESNO 17, CALIFORNIA	Valley Foundry & Machine Works
NEW HAVEN, CONNECTICUT	Macalaster Bicknell Company
ATLANTA, GEORGIA	Southern Scientific Company
CHICAGO 44, ILLINOIS	Fred S. Hickey, Inc.
NEW ORLEANS, LOUISIANA	W. H. Curtin & Company
CAMBRIDGE 39, MASS.	Macalaster Bicknell Company
ST. LOUIS 4, MISSOURI	Stemmerich Supply, Inc.
LODI, NEW JERSEY	Mooney Brothers Corporation
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PITTSBURGH 19, PA.	Fisher Scientific Company
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SEATTLE 4, WASHINGTON	Scientific Supplies
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VANCOUVER, B. C., CAN.	Scientific Supplies

Corning means research in Glass

PYREX

CORNING GLASS WORKS

26 Crystal Street, Corning, N. Y.

Please send me the material checked below:

"PYREX brand 'Double-Tough' Glass Pipe and Fittings Catalog" (EA-3) ☐

"PYREX brand Glass Pipe in the Process Industries" (EA-1) ☐

"PYREX brand Cascade Cooler Bulletin" (PE-8) ☐

Data sheet on Fractionating Columns ☐

Name..... Title.....

Company.....

Address.....

City..... Zone..... State.....

NOTED AND QUOTED

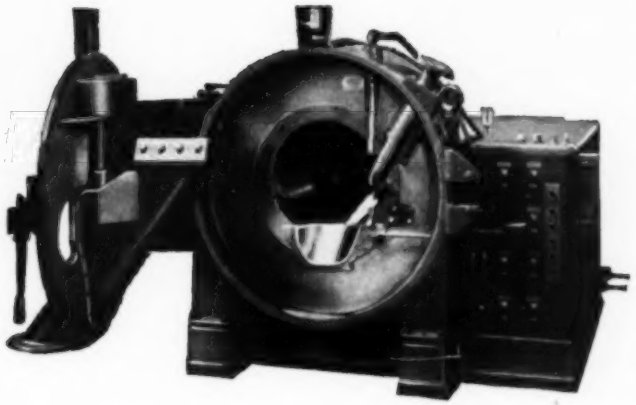
There Are Limits

I came upon an old violinist who was highly skilled in his art, but knew nothing about science. In fact, after a few words with him, I found that he knew no more about acoustics than did Michelangelo. I said to him: "My friend, I have been watching you play that instrument and I think that I may be able to tell you how to play it better, for I am a student of acoustics and know all about the laws of sound. With my knowledge and your skill, I am sure it should be possible to play the violin better than you play it." "Very well," says the old violinist, "here is the violin—play it." "Oh, please," I say, "not so fast. I wish to start with something much more fundamental. Indeed, I do not know that I wish to use that instrument at all. Indeed, it seems to me a very stupid instrument, with no scientific background. It is strung with a cat's inside and played with a horse's tail. It has a form dictated by no scientific principles. I would like to study a very simple case first." And so I proceed to suspend a simple stretched string between two fixed points in space and to discuss all the various modes of vibration. I explain how the frequency of vibration determines the pitch, how the overtones determine the quality and so forth. The old violinist, much impressed, but much bewildered, says: "All right, here is the bow; now let us play it." On drawing the bow across the string, the old violinist hears nothing, for we all know that a string so mounted would emit practically no sound at all. The old violinist complains that he cannot hear anything, but I feel that it is very unreasonable of him to insist upon what it seems is the relatively minor matter of hearing something and proceed to argue that it is much better to understand what you do not hear than to hear what you do not understand. But the old violinist is sad about this matter and he goes away a little comforted by the fact that although he may not know what he is doing, he knows how to do it.

Now unfortunately the man of practical affairs has not the opportunity, so frequently afforded to the man of pure science, of choosing his own battleground and even the antagonists with whom he will contend. The man of science fashions his weapons and invents them to his liking. Then he seeks an enemy against whom he may use them with the greatest efficiency. Some-

(*Continued on page 28*)

BAKER PERKINS EQUIPMENT FOR EFFICIENT *CENTRIFUGATION*

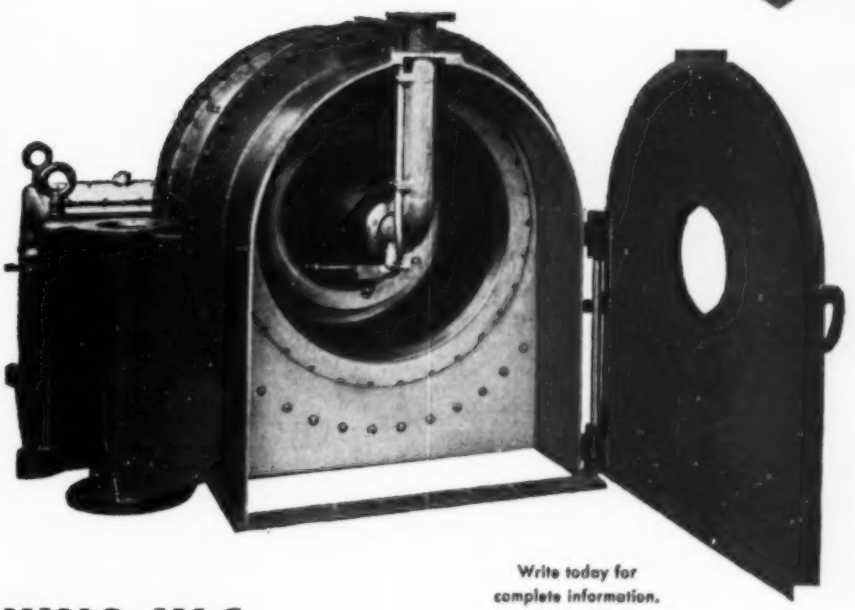


B-P Type HS Universal Filtering Centrifugal: Fully automatic, requires no operator attention, but can be equipped with manual controls. Simple, trouble-free cycle controller handles complicated centrifugation cycles easily — compensates for process variables. Easy change to almost any filter media keeps maintenance costs low. Constant speed drum rotation reduces power requirements. In capacities from laboratory sizes to 16,000 lbs. per hour.

B-P Type S Continuous Centrifugal: Continuous operation requires no timing or cycle controllers. No scrapers, baffles, rakes or plows to break down delicate crystals. Constant speed drum rotation keeps power requirements low. Rugged construction insures long service with very little maintenance. In capacities from laboratory sizes to 48,000 lbs. per hour.

Above: Type HS Universal Filtering Centrifugal for centrifugation of a wide range of filterable solid-liquid slurries.

Right: Type S Continuous Centrifugal for centrifugation of a wide range of relatively free-draining crystalline, granular and fibrous materials.



Write today for complete information.

BAKER PERKINS INC.

280

CHEMICAL MACHINERY DIVISION • SAGINAW, MICHIGAN

NOTED AND QUOTED

(*Continued from page* 10)

times when victory has been attained, the territory conquered is rather barren, but he may care little for this if the fight has been a good one. Sometimes the acquired territory is rich in values of many kinds, in which case the inventor receives much kudos for the benefits he has brought to mankind. He is given credit for having unselfishly worked for the good of mankind. Alas, I fear that in this matter there is a good deal of hypocrisy. In 90 per cent of the cases he has worked on the job because he liked the job . . . . If the future should give utilitarian value to his discoveries, he would probably be as surprised as anyone else at such a consummation of his efforts.

As I have said, the practical man has not the opportunity of choosing his territory for the battle and those who support him are not willing to look far into the future and hazard the belief that what he does today may be of great value then but not now. The practical man has to meet the problems as they come to him. Even if some kind spirit should reveal to him the ultimate fundamentals at the back of his problems, it might not be practicable to find the solution for his immediate task by tracing the story from the fundamentals to the end point. Even though the problem might be one of no perplexity in the sense that the train of relationships could be visualized, it might be one of great complexity, so that its solution was not realizable within the limits of the skill of man.

The Engineer and The Scientist
W. F. G. Swann

Overmechanization

Back in the twenties, soon after the combine wheat harvester came into widespread use on the prairie wheatlands, commercial bakers began to have trouble maintaining the quality of their bread. The difficulty was traced to a change of character in the flour that was milled from the combine-harvested grain. When the conventional binders were used the bundles of wheat were commonly shocked in the field and left until threshing time. During this period, a little of the grain would usually sprout. The sprouting would be insignificant—not enough to damage the crop in normal weather—but it did cause certain diastatic and proteolytic enzymes to form which were found to be beneficial in breadmaking.

When the binders were replaced by the combines, the grain was not left in

(*Continued on page* 32)

CHEMICAL PROCESS NEWS

PUBLISHED BY CHEMICAL PROCESS DIVISION, THE M. W. KELLOGG COMPANY JUNE 1954

NOTES ON

CUMENE

Cumene jumped into prominence during the last war when it was needed in large quantities for its anti-knock properties in aviation gasoline. More recently, renewed interest has developed in the chemical as a starting point in the manufacture of phenol.

***

To supply the sudden wartime demand for cumene, Kellogg designed and built four plants which were outstanding producers. In addition to this and subsequent post-war experience, Kellogg is currently building another cumene plant for a U. S. chemicals manufacturer as part of complete facilities for producing phenol.

***

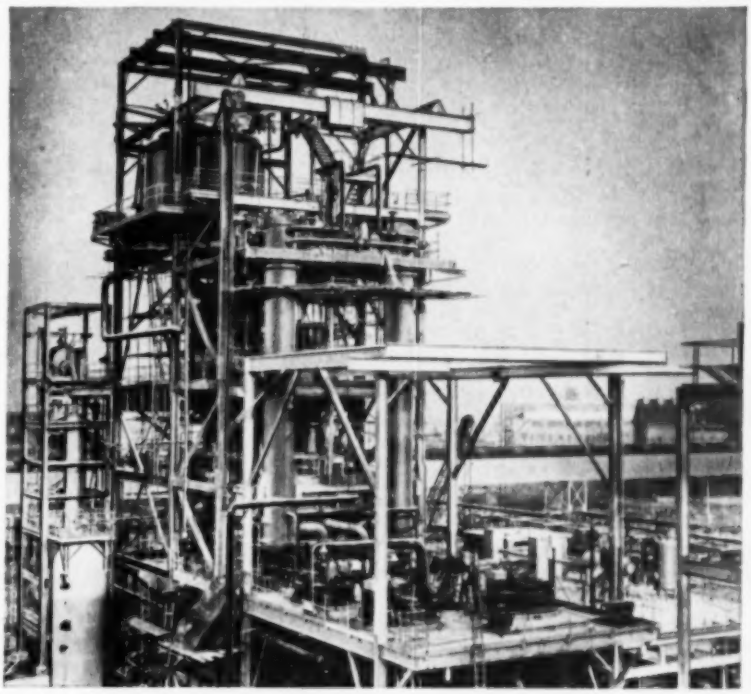
Heart of Kellogg's cumene process is a copper pyrophosphate catalyst developed in Kellogg's Jersey City, N. J. laboratory. Unique to the Kellogg process, and utilized in all of the plants the Company has built and is now building this catalyst gives the process two of its most important points of superiority —higher yields and a higher purity.

***

Copper pyrophosphate is extremely selective in the propylene-benzene reaction. Since it does not alkylate ethylene if present in the feed, high purity cumene required for phenol production can be obtained without removing ethylene from the feed or ethyl benzene from the final product, one of which steps would otherwise be required.

***

As an illustration of yield advantages, over-all conversion of benzene to cumene of other processes are described as falling in the range of 90 to 93%, based on benzene. By contrast, commercial data from Kellogg-built plants indicate yields ranging from 95 to 97% when copper pyrophosphate is employed.



Lower Operating Costs, Better Yields In Fluid Phthalic Process

Two phthalic anhydride plants currently under construction in Europe highlight not only the growing importance of this chemical abroad, but also the economic attractiveness of Kellogg's Fluid process for manufacturing it.

One of the two plants which is shown in the photo above is nearing completion in England under the supervision of the Kellogg International Corporation. The other is being built for a major chemical manufacturer on the Continent. When completed, they will have a combined yearly production of more than 40 million pounds of phthalic anhydride. In both cases, the product is obtained by oxidizing naphthalene in the presence of a fluidized solid catalyst.

Kellogg's Fluid process offers a number of distinct advantages over conventional processes with fixed beds. The Fluid catalyst principle makes for improved temperature control and results in optimum operating conditions. The efficiency obtained allows the use of less air—in some cases as much as 50% less—and better heat recovery.

In addition, yields are up to 5–10% higher; the product is of greater purity: and large Fluid plants can be operated with no more personnel than are required for fixed bed units of considerably smaller capacity.

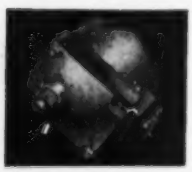
For further information, technical data, etc., relating to chemical or petrochemical processing, write

The "inside" story of *ElectroniK* instruments

Maybe you've never seen what's inside the case of an *ElectroniK* instrument. And even if you have, you might not realize how each component has been painstakingly refined to contribute its share to the overall performance and dependability of the instrument. Three of these components in particular—the converter, "Continuous Balance" amplifier and the balancing motor—are key members of the *ElectroniK* team with which you should get acquainted.

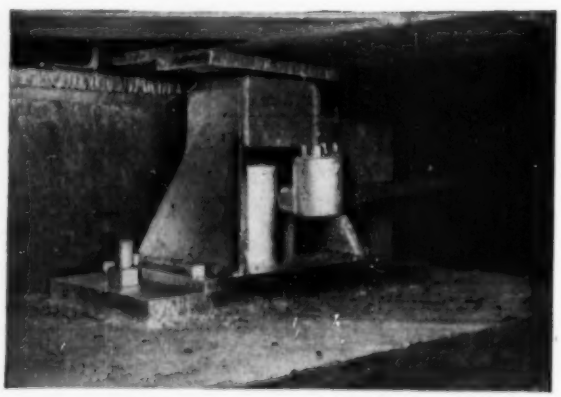
The Converter is what transforms tiny direct-current signals from the thermocouple or other sensing element into an alternating voltage that the amplifier can conveniently handle. In principle, it is somewhat like the vibrator in your automobile radio. But because it deals with such small bits of electrical energy, it has been designed of carefully selected materials which prevent the introduction of misleading signals into the measuring system. It is hermetically sealed against the effects of dust, humidity and atmospheric pressure change, and is shielded against stray electrical and magnetic fields.

The "Continuous Balance Amplifier" boosts the incoming signals by millions of times . . . makes them strong enough to operate the balancing motor. Although it looks like part of a radio chassis, few communications circuits could equal it for quality. It uses standard, easily obtained parts, which are operated far below their normal ratings to insure exceptionally long life. The circuit has great stability against drift and pick-up, and is thoroughly temperature compensated.

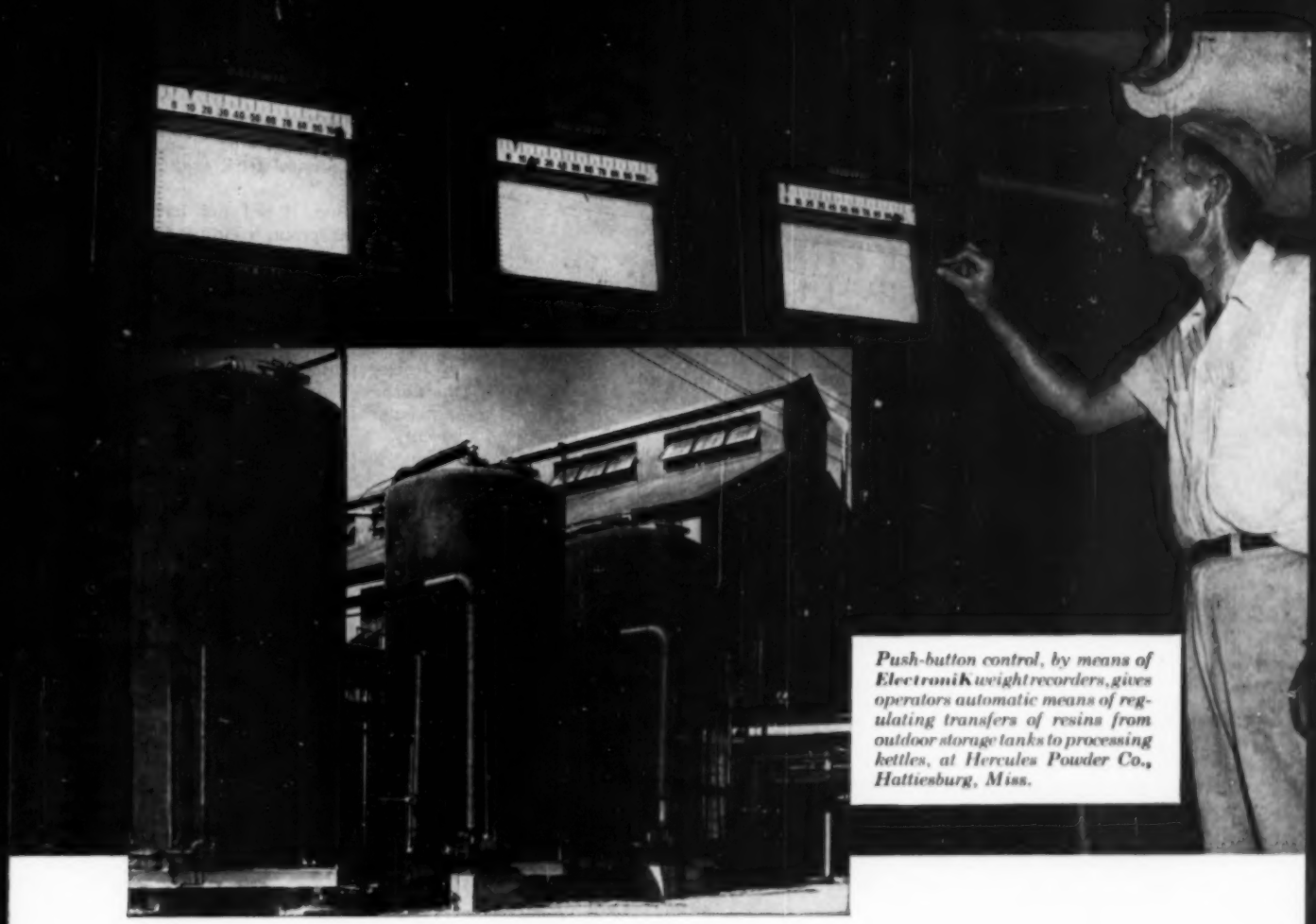


The Balancing Motor does the work of moving the pointer, recording pen and any control devices that may be incorporated in the instrument. It packs plenty of power into a small space . . . gives ample torque to give fast, accurate positioning whenever the amplifier calls on it. Totally enclosed, the motor is impervious to dust, dirt and changes in mounting position.

Electrical weighing system measures batch



Four Baldwin-Lima-Hamilton SR-4 load cells like this one are built into the pillar mounts of the storage tanks. Connected in series to an ***ElectroniK*** *recorder, they detect total weight of the tank. An adjustment in the instrument cancels out dead weight, to give direct reading of weight of tank contents.*



Push-button control, by means of ElectroniK weight recorders, gives operators automatic means of regulating transfers of resins from outdoor storage tanks to processing kettles, at Hercules Powder Co., Hattiesburg, Miss.

ingredients accurately . . . *automatically*

NEED to measure transfers of materials? The automatic weighing system that Hercules Powder Co. uses for measuring resin ingredients at their Naval Stores plant may give you some new ideas.

The problem here was to transfer the required weights of various viscous liquids from outdoor storage tanks into processing kettles. The answer is electrical weighing by means of a fully automatic system that utilizes Baldwin-Lima-Hamilton SR-4® strain gage load cells and *ElectroniK* strip chart controllers. This system controls weight directly without the complications that go with conventional flow metering.

Each tank is weighed continuously by four load cells mounted under the tank-supporting beams. Output of the load cells is fed to an *ElectroniK* weight recorder. To deliver a given amount of liquid into a processing kettle, the operator sets a selector switch and moves the instrument control index downscale by the required poundage. Pushing a button starts the cycle. Without further attention, the system pumps out the desired poundage of fluid, automatically stops the pump, records the weight delivered and steam-purges connecting pipes.

Through more accurate measurement, this system helps to produce greater quality and uniformity in resin formulas. It saves time and labor, too, by giving a continuing inventory for cost-accounting purposes.

Electronic weighing systems offer endless opportunities for measuring materials in storage, or in motion. Your nearby Honeywell engineer will be glad to discuss the possibilities in your own plant's operations . . . and he's as near as your phone.

MINNEAPOLIS-HONEYWELL REGULATOR CO., *Industrial Division*, Wayne and Windrim Avenues, Philadelphia 44, Pa.

● **REFERENCE DATA:** Write for Data Sheet No. 10.10-1a, "Unit Measuring Systems with Baldwin Electric Strain Gages," and for Catalog No. 1531, "*ElectroniK* Controllers."

MINNEAPOLIS
Honeywell
BROWN INSTRUMENTS
First in Controls

NOTED AND QUOTED

(Continued from page 28)

the field. Thus it did not have the opportunity to sprout, it did not develop the needed enzymes, and the flour that was milled from the wheat did not perform properly in the bakery.

With the cause of the trouble known, the remedy was obvious—add enzymes to replace those no longer present in the flour. This was first done by malting some wheat (that is, allowing it to sprout), drying it, and grinding it into a flour that could be mixed with the regular flour.

Rohm & Haas Reporter

Man—The Measure of All Things

. . . But survival has a time dimension which says that power consists of more than strength of arms. Short-term survival may depend on the knowledge of nuclear physicists and the performance of supersonic aircraft, but long-term survival depends alone on the character of man. Our scientific, economic, and military accomplishments are rooted in the human quality which produces them. In the last analysis, all of our knowledge, all of our action, all of our progress succeeds or fails according to its effect on the human body, mind, and spirit. While we concentrate our attention on the tools of economics and war, we must not neglect the basic means of surviving, the basic reason for survival: man himself.

Charles A. Lindbergh
in a speech before the
Institute of Aeronautical Sciences

What Think You of the Scientist?

The scientist has strong grounds for the plea that he is "misunderstood." One moment he is the evil genius whose handiwork threatens to pulverize our planet; the next minute he is a magician who can provide the full answer to any problem.

Either characterization, of course, is a misconception. Yet a surprising number of scientists themselves harbor the latter, romantic, view of the scientist, especially the creative scientist. There is a feeling that intellect, proper training, and environment virtually assure creativity—the force that is the cornerstone of research. Among the elements of creativity that are less tangible, but at least as potent as degrees and equipment, are the homely virtues of imagination, initiative, perseverance, and that imponderable called chance.

Harold K. Work
Over the Director's Desk
N.Y.U. *Research Review*

Opinion and comment

CHEMICAL ENGINEER AND EQUIPMENT MANUFACTURER

Chemical engineering is a profession of many facets. All however must function towards a single ultimate goal—the process plant. The practice of chemical engineering is highly dependent on the availability of processing equipment which will perform the functions as desired. As the architect is dependent on the products of stone, steel, glass, and a host of other materials, the chemical engineer must have his mixer-equipped jacketed reaction pressure vessels, and a thousand and one other items.

On one hand, chemical engineers are striving to improve their understanding and predictability of processes and operations in the ideal state. Then, at the same time, other chemical engineers are coping with the problems of getting equipment that will reasonably fulfill the ideal requirements, yet perform within economic and safe limits of practical operating needs. As process plants become fairly automatic in operation to the degree now seen in many petrochemical plants, such relatively simple operations as continuous pumping or compression may become nightmares of operating complications.

As this happens, or is anticipated at the design stage, the equipment manufacturer becomes an important ally, who brings to bear on the problem the full background of his experience with failures and successes of the past, seasoned by his expert knowledge of his materials of construction, mechanical design, and manufacturing techniques.

C.E.P. wishes to salute the equipment manufacturer and to call to the attention of all chemical engineers his valuable contributions to chemical processing or applied chemical engineering.

In the months to come C.E.P. expects to bring to its readers a series of communications which will, we believe, materially aid in bringing about a better practical understanding of the equipment manufacturers' knowledge and facilities. The first of these appears in this issue, under the title "Cost Estimation—Fabricated Plant Equipment," by James Donovan, an authority on the subject of relationship between design selections and costs of fabrication. Jim's treatment of the subject is both reasonably brief and yet packed with information of practical value.

Somewhat along the same pattern is the article "Plastics for Chemical Engineering Construction" by George Laaff. Though this conveys a good deal of definitive information about the properties of unplasticized polyvinylchloride, as a material of construction, it ends up with a likewise thorough instruction on how to plan and execute actual equipment fabrications out of this easily worked and yet highly corrosion-resistant material. Also related is "Elements of Dust and Mist Collection" by C. E. Lapple, which sets the scene for a series of equipment articles to be run in C.E.P.

Let us hope that in time the combination of C.E.P. and the A.I.Ch.E. meetings will be successful as important factors in effecting a better partnership, such as existed in the early days when the chemical engineers and the equipment builders had close acquaintance on every aspect of equipment selection, procurement, manufacture, installation and operation.

SUN CULTISTS

Next January, in the heart of the "sun-country" a world symposium on applied solar energy will take place. This will bring together the leading workers from throughout the world, who will discuss progress and plans for undertaking the harvest of industrially important quantities of what must ultimately become the world's main direct source of energy.

Among the avenues appearing most attractive at present are the heat pump, forced culture of lower order plants and animals, applied photosynthesis, more efficient absorption of solar radiation to lengthen growing seasons, solar-energized stills and the new photoelectric "battery."

Some of these developments are in reality quite old and their practical application awaits the overcoming of scale-up and other problems standing in the way of economic practicality. In other cases matters appear to be far enough advanced to warrant serious consideration by investors, marketers, and others who will probably be called upon in the not-too-distant future to provide the wherewithal and create acceptance by the public and stockholders alike for the first major industrial steps. It is encouraging to note that bankers and industrial leaders, as well as technologists, educators and others are among the sponsors.

The symposium is being announced by Stanford Research Institute and will be held in Arizona. It is very much to be hoped that chemical engineers will be taking a keen interest in this, inasmuch as their ministrations of the final development of practical commercial phases of many of the above-mentioned avenues, will doubtless be of critical necessity.

CONFUSED ATOM

If it's beginning to look as if atomic power is just around the corner, and then isn't and then is again, just charge the whole matter off to spring. This spring in particular has seen the interests of several young men turn toward the making of "powerfull" predictions, and if we hadn't just finished digging the true facts out of expert sources, we too would be confused.

Just this morning the mail brought us the report on the latest prediction—atomic power in five to ten years (with which we agree)—but then goes on to say, however, "Chemical separations plants are not going to be necessary." We looked at this admittedly with wide-eyed trepidation, inasmuch as our upper vertebral structures (approved C.E.P. term for "necks") are way out on the point that such plants *are* necessary. C.E.P. (May, 1954) goes to great lengths to explain why.

It wasn't until two pages later that the mystery of the reactors minus chemical plants was solved with the statement that such is dependent on "development of an adequate long-burn-up fuel element which is not yet available . . . . The effort to develop [such] is a major undertaking with many aspects and a number of possible avenues of solution . . . . Though problems connected with this development are far from actual solution, there exists among the many groups of experts a great deal of confidence that an adequate solution will be found."

Whether or not this fuel panacea will *ever* be found, is a question no one can answer. It is an interesting conjecture however and we extend our appreciation to F. K. McCune of G.E. Atomic Products Division for bringing it out for speculation.

In the meantime we are standing pat on our original position that chemical separations plants will be essential parts of at least the first economically competitive nuclear power plants, and that the achievement of such practicality will depend to a great extent on the efforts and specialized talents of chemical engineers.

J.B.M.

EVEN THE TOUGHEST ACIDS *Shun this Joint*

In acid-proof brick floors — in any type of corrosion-resistant masonry — the joint between the bricks is the critical point. Ordinary mortar joints won't do. Even many specialized "acid-proof" cements will handle only a limited range of acids. Others will handle acids but fail quickly under alkali attack.

But a joint made of Durisite will resist *both* acids and alkalis — will stand up under time, under abrasion, under impact.

Wherever corrosion is a problem you'll find materials and products by U. S. Stoneware on the job. Corrosion specialists since 1865, we work with many materials — with plastics, with rubber, with ceramics, with metals.

U. S. Stoneware's versatile Tygon plastics serve all industry: as clear, flexible hose for piping sensitive fluids, foods, pharmaceuticals, whole blood and blood plasma; as paint to protect concrete and metal surfaces from attack by corrosive fumes; as linings for tanks containing corrosive chemicals. In ceramics, "U.S." white chemical porcelain, and chemical stoneware, are fabricated into large and intricate shapes for chemical plant usage. In rubber—hundreds of specialized compounds meet highly exacting and critical needs. And in the new field of metallic oxides, U. S. Stoneware's ALITE offers solutions to corrosion problems once thought insurmountable.

U.S. PRODUCT OF
STONEWARE
Akron 9, Ohio

The U. S. Stoneware Co. has prepared two booklets which will prove helpful to any company concerned with any type of corrosion-resistant masonry. "**HOW TO BUILD AN ACID-PROOF BRICK FLOOR**" *and* "**CORROSION-RESISTANT MASONRY CONSTRUCTION GUIDE**" *are down-to-earth books with a wealth of pertinent, practical information. They are free, by request on your company letterhead. Write: The U. S. Stoneware Co., Dept. _____, Akron 9, Ohio.*

375 D

Plastics for Chemical Engineering Construction

—unplasticized polyvinylchloride

George S. Laaff Bolta Products, Lawrence, Massachusetts

A Division of General Tire & Rubber Co.

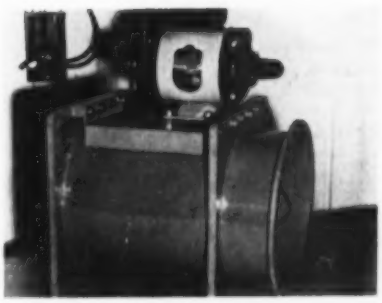
In spite of the development of various stainless steels and alloys, corrosion takes a toll of nearly six billion dollars each year in the United States, in addition to incalculable indirect losses caused by shutdowns, loss of products, and cost of overdesign. The National Bureau of Standards has estimated that corrosion of underground pipe in this country exacts an annual toll of six hundred million dollars.

The problems, analyses, and cure of corrosion are complex. Basically corrosion is disintegration of a surface by electrochemical action. As there is no single cause, corrosion can be explained only by study of each case. Corrosion or electrolytic action starts whenever an electric potential exists. Contact of dissimilar metals, chemical concentration or concentration cells, the lack of homogeneity within the metal, and transient direct currents are some of the causes of anodic decomposition.

Because of their electrical properties plastics do not suffer this type of surface reaction. Plastics are relatively new but have performed well in the battle against corrosion. Chemical equipment has been successfully fabricated from thermosetting plastics such as phenolic or furfuryl alcohol resins, rubber-modified phenolics, polyester-Fiberglas, melamine-Fiberglas, and from thermoplastics including cellulose acetate-butyrate, polymethyl methacrylate, polyamides, polyisobutylene, polytetrafluoroethylene, polymonochlorotrifluoroethylene, styrene mixed polymers, polyethylene, polyvinylidene chloride, and polyvinyl chloride.

In the oil industry there are four primary causes of decay: salt water, sour crude oil, corrosive earth, and electrolytic action. Cellulose acetate-butyrate has been successful where all these causes exist. Typical uses include disposal well lines, vent lines, slurry lines, and natural gas lines. The pipe has a smooth inner surface which promotes a greater volume flow of liquid than that of a steel pipe of the same diameter. Another advantage is that paraffin, which clogs steel oil lines, will not adhere to the inner wall of a butyrate pipe. This resin, however, does not possess the high chemical resistance of others, and is easily degraded by solvents and strong alkalies.

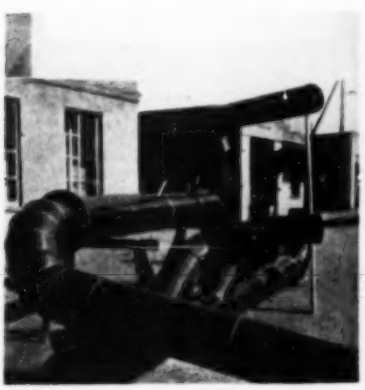
A strong bid for a major share of hot chemical handling equipment is made by Fiberglas-reinforced polyesters. Their thermosetting nature and good chemical resistance make them superior

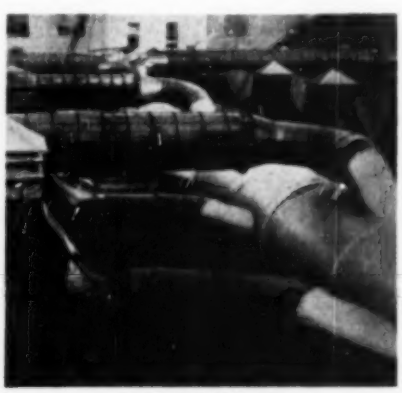


Tube-axial fan.

to other plastics at temperatures above 170° F. Hand lay-up of air-drying or oven-curing polyesters on glass mats make the fabrication of complex shapes comparatively easy. Polyester-Fiberglas pipe manufactured by continuous process is now available for hot processes. This material has strength and toughness with little weight, properties which make polyesters substitutes for steel in corrosive atmospheres too severe for ferrous metals. Disadvantages of polyester are poor flex fatigue and poor water resistance at elevated temperatures.

Polyethylene, a thermoplastic resin with remarkable chemical inertness, is exceptionally resistant to acids (oxi-





Ductwork fabrication

Table 1.—Physical Properties of Some Structural Plastics

	UPVC	Fiber-glas	Poly-ethylene	Saran
Specific gravity A.S.T.M. D792-48T	1.4	1.6	0.9	1.7
Tensile strength lb./sq.in. A.S.T.M. D638-49T	8,500	40,000	2,500	5,000
Modulus of elasticity in tension—lb./sq.in. D638-49T	4.5×10^5	20×10^5	2×10^4	0.8×10^5
Flexural strength—lb./sq.in. A.S.T.M. D671-49T	16,000	30,000	1,700	16,000
Compressive strength lb./sq. in. A.S.T.M. D695-49T	10,000	40,000	.....	8,000
Hardness (Rockwell) A.S.T.M. D785-48T	M-60	M-100	R-11	M-60
Heat distortion ° F.—66 lb./sq.in. D68-45T	165° F.	300° F.	120° F.	160° F.
Coefficient of expansion per 1° C. A.S.T.M. D694-44	8×10^{-5}	8×10^{-6}	4×10^{-4}	16×10^{-5}
Thermal conductivity cal./sec./cm.²/cm.²/° C. C-177	4×10^{-4}	.....	8×10^{-4}	3×10^{-4}
Specific heat cal./gm.° C. A.S.T.M. calorific method	0.24	0.25	0.55	0.32
Flammability D568-48	Self ext.	Slow	Burns	Self ext.
Dielectric constant @ 1 megacycle D150-47T	3	4.5	2.3	4
Water absorption % 24 hr. @ 25° C. A.S.T.M. D570-42	0.05	0.6	0.01	0.05

Table 2.—UPVC—Applications

1. Absorption Apparatus
2. Agricultural Spraying Equipment
3. Agitators
4. Bearings
5. Bleaching Equipment
6. Bottles
7. Cans
8. Centrifugal Pumps
9. Cooling Systems
10. Cooling Coils
11. Dipping Baskets
12. Dust Arrestors
13. Exhaust Fans
14. Filters
15. Floats
16. Fume Ducts and Tunnels
17. Fume Hoods
18. Fume Stacks
19. Gas Meters
20. Gears
21. Humidification Equipment
22. Intermediate Printing Blades
23. Insulators
24. Laboratory Equipment, Table, Sinks
25. Nuts and Bolts
26. Pharmaceuticals
27. Plating Barrels
28. Plenum Chambers
29. Pumps
30. Reaction Tanks
31. Reaction Towers
32. Scoops
33. Sizing Troughs & Vats
34. Splash Covers
35. Spinneretta Adaptors
36. Strainers
37. Suction Fans
38. Switch-boards
39. Switch Insulators
40. Tanks
41. Tank Liners
42. Trays
43. Transparent Windows
44. Valves
45. Ventilators
46. Wire Insulation

dants excluded), alkalies, and certain solvents. Attractive because of low cost and ease of fabrication, sheets are readily welded and can be formed and machined by inexpensive equipment. Fabrication of various industrial equipment such as tank liners, fume ducts, and valves is easily accomplished. Polyethylene exhibits a wide temperature range of flexibility and an impact strength that varies little between −10° F. and 80° F.; however use is limited to about 130° F. because of its low softening point. This material is useful in the electrical industry because of low dielectric constant, high dielectric strength, low power factor, and high surface and volume resistivity.

Polyethylene has, however, a number of disadvantages.

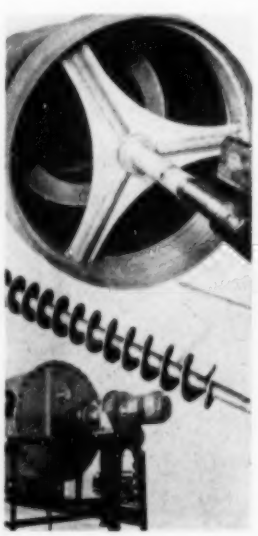
1. Polyethylene cannot be used as a structural material because of its low-flexural strength. Any construction, except small articles, must be supported by materials like steel or wood. Such supports increase costs and make construction more involved.
2. Polyethylene pipe must be used with caution because of its low burst strength.
3. Polyethylene is among the poorest structural materials where creep is involved. Constructions using polyethylene must be so designed that stresses will be negligible.

Methods of processing plastics include stationary casting, melt casting, or centrifugal casting; compression, extrusion, injection, transfer, and slush molding; laminating, blowing, drawing, and flame spraying. Most of the thermosetting and thermoplastic materials may be machined readily, sawed, turned, milled, bored, punched, and polished on ordinary wood- and metal-working tools. Slight modifications and precautions must be observed, but the adaptation of skills and tools is not difficult.

Plastics have excellent chemical resistance and are nonconductors. Generally their low heat resistance is sufficient in a multiplicity of processes where aqueous solutions at temperatures of from 40° to 160° F. are encountered. The specific selection of a plastic is determined by a balancing of the basic physical and chemical properties, general processability, fabricating possibilities, and, of course, economic factors (Table 1). For the favorable balance of these properties, unplasticized polyvinyl chloride is being chosen for apparatus in chemical- and food-processing plants and in the photographic, tanning, textile, and electroplating industries.

Polyvinyl chloride is a thermoplastic linear macromolecular chain produced by the additional polymerization of vinyl chloride. The polymer or resin is commercially available as a fine white powder. The aim is a narrow band of molecular weight, and a narrow low-molecular-weight band appears to be preferred to a wide band of high-molecular weight, as chemical resistance is governed by the low ends in the molecular-weight distribution. Controls for pinpointing such a polymerization are most exacting. Polymerization must be carried out to unheard of accuracy—not ±1° F., but perhaps ±1/10° F. to control the molecular-weight distribution in the band.

The resin is processed between 350° and 400° F. in the presence of internal



(Left) Rotary drum filter.

(Right) Upper: Detail of welding construction. (Lower): 6-ft. diam. absorption column plate.

Table 3.—UPVC—Resistance to Organic and Inorganic Materials

	73°F	140°F
Magnesium Chloride	R	R
Magnesium Hydroxide	R	R
Magnesium Nitrate	R	R
Magnesium Sulfate	R	R
Malic Acid	R	
Maleic Acid	R	R
Mercuric Chloride	R	R
Mercuric Cyanide	R	R
Mercurous Nitrate	R	R
Mercury	R	R
Methyl Alcohol	R	R
Methyl Chloride	NR	NR
Methyl Ethyl Ketone	NR	NR
Methyl Sulfate	R	R
Methyl Sulfuric Acid	R	R
Methylene Chloride	NR	NR
Mixed Acid	R	R
Naphtha	R	R
Naphthalene	NR	NR
Nickel Chloride	R	R
Nickel Nitrate	R	R
Nickel Sulfate	R	R
Nicotine	R	R
Nicotinic Acid	R	R
Nitric Acid, Anhydrous	NR	
Nitric Acid, 68%	R	R
Nitric Acid, 10%	R	R
Nitrobenzene	NR	NR
Nitrous Oxide	R	R
Oronol	R	R
Oils & Fats	R	R
Oleic Acid	R	R
Oleum	NR	
Oxalic Acid	R	R
Ozone	R	R
Palmitic Acid	R	R
Perchloric Acid 70%	R	NR
Perchloric Acid 10%	R	NR
Phenol	R	NR
Phenylhydrazine	NR	
Phenylhydrazine Hydrochloride	R	NR
Phosgene, liquid	NR	
Phosgene, gas	R	
Phosphoric Acid 85%	R	R
Phosphoric Acid 10%	R	R
Phosphorus (yellow)	R	
Phosphorus Pentoxide	R	
Phosphorus Trichloride	NR	
Picric Acid	NR	NR
Potassium Bicarbonate	R	R
Potassium Dichromate	R	R
Potassium Borate	R	R
Potassium Bromate	R	R
Potassium Bromide	R	R
Potassium Carbonate	R	R
Potassium Chromate	R	R
Potassium Chlorate	R	R
Potassium Cyanide	R	R
Potassium Ferricyanide	R	R
Potassium Ferrocyanide	R	R
Potassium Fluoride	R	R
Potassium Hydroxide	R	R
Potassium Nitrate	R	R
Potassium Perborate	R	R
Potassium Perchlorate	R	R
Potassium Permanganate 10%	R	R
Potassium Persulfate	R	R
Potassium Sulfate	R	R
Propane	R	
Propargyl Alcohol	R	R
Propyl Alcohol	R	R
Propylene Dichloride	NR	NR
Selenic Acid	R	
Silicic Acid	R	R

	73°F	140°F
Silver Cyanide	R	R
Silver Nitrate	R	R
Sodium Acetate	R	R
Sodium Benzoate	R	R
Sodium Bicarbonate	R	R
Sodium Bisulfate	R	R
Sodium Bisulfite	R	R
Sodium Bromide	R	R
Sodium Carbonate	R	R
Sodium Chlorate	R	R
Sodium Chloride	R	R
Sodium Cyanide	R	R
Sodium Ferricyanide	R	R
Sodium Ferrocyanide	R	R
Sodium Fluoride	R	R
Sodium Hydroxide	R	R
Sodium Hypochlorite	R	R
Sodium Nitrate	R	R
Sodium Nitrite	R	R
Sodium Sulfate	R	R
Sodium Sulfide	R	R
Sodium Sulfite	R	R
Stannic Chloride	R	R
Stannous Chloride	R	R
Stearic Acid	R	R
Sulfur	R	R
Sulfur Dioxide (gas)	R	R
Sulfur Dioxide (liquid)	R	NR
Sulfur Trioxide	R	R
Sulfuric Acid 96%	R	R
Sulfuric Acid 80%	R	R
Sulfuric Acid 33%	R	R
Sulfurous Acid	R	R
Tannic Acid	R	R
Tartaric Acid	R	R
Tetraethyl Lead	R	
Tetrahydrofurane	NR	NR
Thionyl Chloride	NR	
Toluol	NR	NR
Tri Butyl Phosphate	NR	NR
Trichlorethylene	NR	NR
Triethanolamine	R	R
Triethylamine	R	R
Trimethyl Propane	R	R
Trisodium Phosphate	R	R
Turpentine	R	R
Urea	R	R
Urine	R	R
Vinyl Acetate	NR	
Zinc Chloride	R	R
Zinc Sulfate	R	R
Bleach 12.5% active Cl2	R	R
Breeder Pellets (deriv. fish)	R	R
Fish Solubles	R	R
Fruit Juices / Pulp	R	R
Gasoline	R	R
Liqueurs	R	R
Molasses	R	R
Photographic Solutions		
D. K. 41	R	R
Dektol Developer	R	R
Kodak Fixer	R	R
Kodak Short Stop	R	R
Rayon Coagulating Bath	R	R
Sea Water	R	R
Silver Plating Solution	R	R
TanningLiquors	R	R
Wines	R	R

	73°F	140°F
Acetaldehyde	NR	NR
Acetic Acid, 10%	R	R
Acetic Acid, glacial	R	NR
Acetic Anhydride	NR	NR
Acetone	NR	NR
Adipic Acid	R	R
Allyl Alcohol 96%	R	NR
Allyl Chloride	NR	NR
Alum	R	R
Aluminum Chloride	R	R
Aluminum Fluoride	R	R
Aluminum Hydroxide	R	R
Aluminum Oxychloride	R	R
Aluminum Nitrate	R	R
Aluminum Sulfate	R	R
Ammonia (gas)	R	R
Ammonia (liquid)	NR	NR
Ammonium Bifluoride	R	R
Ammonium Carbonate	R	R
Ammonium Chloride	R	R
Ammonium Fluoride 25%	R	NR
Ammonium Hydroxide 28%	R	R
Ammonium Metaphosphate	R	R
Ammonium Nitrate	R	R
Ammonium Persulfate	R	R
Ammonium Sulfate	R	R
Ammonium Sulfide	R	R
Ammonium Thiocyanate	R	R
Amyl Acetate	NR	NR
Amyl Chloride	NR	NR
Aniline	NR	NR
Aniline Hydrochloride	NR	NR
Anthraquinone	R	
Anthraquinonesulfonic Acid	R	R
Antimony Trichloride	R	R
Aqua Regia	R	R
Arsenic Acid 80%	R	R
Arylsulfonic Acid	R	NR
Barium Carbonate	R	R
Barium Chloride	R	R
Barium Hydroxide	R	R
Barium Sulfate	R	R
Barium Sulfide	R	R
Benzaldehyde	NR	NR
Benzene	NR	NR
Benzoic Acid	R	R
Bismuth Carbonate	R	R
Borax	R	R
Boric Acid	R	R
Bromic Acid	R	R
Bromine, liquid	NR	NR
Bromine, water	R	R
Butane	R	
Butadiene	R	R
Butanol, primary	R	R
Butanol, secondary	R	NR
Butyl Acetate	NR	NR
Butyl Phenol	R	NR
Butylene	R @ 0°F	
Butyne Diol	R	NR
Butyric Acid	NR	NR
Calcium Carbonate	R	R
Calcium Chlorate	R	R
Calcium Chloride	R	R
Calcium Hydroxide	R	R
Calcium Hypochlorite	R	R
Calcium Nitrate	R	R
Calcium Sulfate	R	R
Carbonic Acid	R	R
Carbon Bisulfide	NR	NR
Carbon Dioxide	R	R
Carbon Monoxide	R	R
Carbon Tetrachloride	R	NR
Cellosolve	R	R
Chloracetic Acid	R	R

	73°F	140°F
Chloral Hydrate	R	R
Chloric Acid 20%	R	R
Chlorine (gas)	R	NR
Chlorine, water	R	R
Chlorobenzene	NR	NR
Chloroform	NR	NR
Chlorosulfonic Acid	R	
Chrome Alum	R	R
Chromic Acid 40%	R	R
Citric Acid	R	R
Copper Chloride	R	R
Copper Cyanide	R	R
Copper Fluoride	R	R
Copper Nitrate	R	R
Copper Sulfate	R	R
Cresol	NR	NR
Cresylic Acid 50%	R	R
Croton Aldehyde	NR	NR
Cyclohexanol	NR	NR
Cyclohexanon	NR	NR
Dextrin	R	R
Dextrose	R	R
Diazo Salts	R	R
Diglycolic Acid	R	R
Dimethylamine	NR	NR
Dioctylphthalate	NR	NR
Ethyl Acetate	NR	NR
Ethyl Acrylate	NR	NR
Ethyl Alcohol	R	R
Ethyl Chloride	NR	NR
Ethyl Ether	NR	NR
Ethylene Bromide	NR	NR
Ethylene Chlorhydrin	NR	NR
Ethylene Dichloride	NR	NR
Ethylene Glycol	R	R
Ethylene Oxide	NR	NR
Fatty Acids	R	R
Ferric Chloride	R	R
Ferric Nitrate	R	R
Ferric Sulfate	R	R
Ferrous Chloride	R	R
Ferrous Sulfate	R	R
Fluorine (gas)	R	R
Fluorosilicic Acid	R	R
Formaldehyde	R	R
Formic Acid	R	NR
Fructose	R	R
Furfural	NR	NR
Glucose	R	R
Glycerine	R	R
Glycol	R	R
Glycolic Acid	R	R
Hexanol, Tertiary	R	R
Heptane	R	R
Hydrobromic Acid 20%	R	R
Hydrochloric Acid 35%	R	R
Hydrochloric Acid 10%	R	R
Hydrocyanic Acid	R	R
Hydrofluoric Acid 48%	R	NR
Hydrogen	R	R
Hydrogen Peroxide 90%	R	R
Hydrogen Phosphide	R	R
Hydrogen Sulfide	R	R
Hydroxylamine Sulfate	R	R
Hypochlorous Acid	R	R
Iodine	NR	NR
Kerosene	R	R
Lactic Acid	NR	NR
Lard Oil	R	R
Lauric Acid	R	R
Lauryl Chloride	R	
Lead Acetate	R	R
Linoleic Acid	R	R
Linseed Oil	R	R
Magnesium Carbonate	R	R

lubricating agents, colorants, and suitable stabilizers which prevent formation of isolated double bonds in the resin molecule and also absorb the hydrochloric acid, which is liberated in an autocatalytic reaction. The processing of unplasticized PVC is a problem, especially in the United States, where higher molecular weight polyvinyl chloride (PVC) resins are produced for optimum physical and chemical properties. Astounding progress, however, has been made in the past six to twelve months. A wide range of unplasticized polyvinyl chloride compounds is available in the form of sheets from 1/32 to 1 in., and of tubing and pipe from ¼ to 6 in. It can be obtained as round bar stock up to 2 in., as solid blocks up to 4 in., and welding rod. Molding compounds are available for transfer and for injection molding into pipe fittings such as 45° and 90° elbows, couplings, tees, unions, caps, plugs, flanges, and other types of joints.

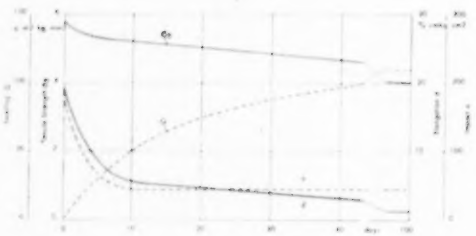
The heavy chemicals, textile, synthetic fiber, electroplating, photographic film, paper, food, and dairy industries are daily finding new uses for unplasticized PVC. This material fills a definite role wherever optimum corrosion resistance or noncontamination is the important characteristic of a structural material. A complete listing of industries and applications is given in Table 2.

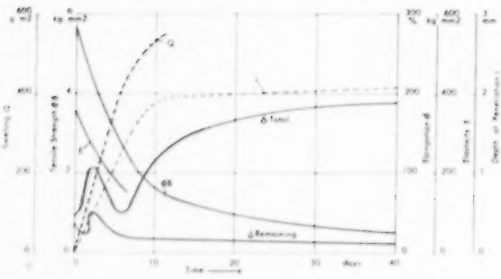
Extensive German experimentation has proved that polyvinyl chloride compounds must be as free of processing modifiers as possible to utilize maximum corrosion resistance. Convertors who had long used plasticizers and practically anything else that would help processing, were tempted to modify their formulations to some extent. These little sins were immediately apparent in subsequent physical and chemical tests. For maximum chemical resistance unplasticized vinyl compound must be as nearly 100% resin as possible.

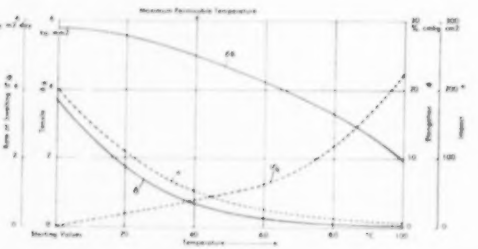
UNPLASTICIZED AND RIGID PVC

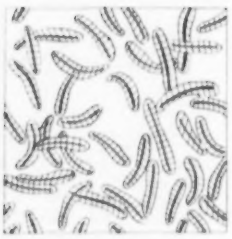
Modified PVC materials with enhanced physical properties are available. An improvement in any one physical property, however, is generally accompanied by a drop in other physical properties, for example, high impact PVC. To develop this it was necessary to accept lower tensile strength and, as in all instances of PVC modification, the chemical resistance of the compound was lowered. In specific cases, however, this compromise of properties significantly widens the scope of use. For example, in submarines the normal impact of UPVC, (< 1 ft. lb./in. of notch) is insufficient and the chemical resistance is in excess of requirements. High impact PVC (> 15 ft. lb./in. of notch) provides the high physical requirements and lower, but satisfactory, chemical resistance to battery acid.

Unplasticized PVC today is purely

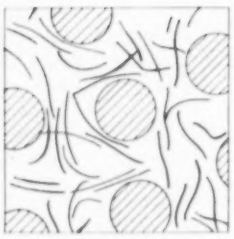








benzene



water

Fig. 1. Resistance of UPVC to aqueous agents (physical properties vs. time).
Fig. 2. Resistance of UPVC to softening agents (physical properties vs. time).
Fig. 3. Resistance of UPVC to aqueous agents (physical properties vs. temperature).
Fig. 4. Left and right: Types of swelling with solvation.

Table 4.—Reagent Effects on Phys. Props. UPVC

Hydrogen Peroxide, 50%

Immersion days	0	60	120	180
Dim. change %				
length		−0.1-+0.1	−0.1	−0.1
width		0-+0.6	−0.2-−1.0	+0.2-+0.4
thickness		neg.	0-+0.4	+0.4
Change in wt. %		−1.5	−1.5-+0.2	+0.1
Change in vol. %		+0.6	−0.3-0.9	+0.5-+0.7
Hardness (Rockwell)	M61-M63	M60-M65	M65-M67	M64-M66
Flex. str.* × 10^3 lb./sq.in.	14.1-14.8	9.0-9.9	11.4-11.9	8.48-9.97
Flex. mod. × 10^3 lb./sq.in.	379.0-420.0	339.0-384.0	354.0-390.0	280.0-339.0
Tens. str. × 10^3 lb./sq.in.	8.4-8.8	8.47-8.69	8.58-9.44	8.54-8.67
Tens. mod. × 10^3 lb./sq.in.	346.0-368.0	355.0-371.0	306.0-350.0	339.0-353.0
Elongation %	105.0-169.5	97.5-120.0	50.0-135.5	120.5-127.5

No apparent change in appearance of specimens after immersion.

Acid, Sulfuric (Conc.) (Sp.gr. 1.835)

Immersion days	0	60	120	180
Dim. change %				
length		−0.1-+0.1	−0.1-−0.2	+0.1
width		−0.2-+1.0	0-+0.4	−0.2-+4.2
thickness		0-+0.4	0-+0.4	−3.4-+0.8
Change in wt. %		neg.	neg.	−0.1-+0.5
Change in vol. %		+0.1-+1.0	+0.1-+0.5	−0.6-+0.9
Hardness (Rockwell)	M61-M63	M64-M65	M64-M68	M66
Flex. str.* × 10^3 lb./sq.in.	14.1-14.8	115.-12.4	8.8-10.6	8.77-9.8
Flex. mod. × 10^3 lb./sq.in.	379.0-420.0	381.0-410.0	347.0-379.0	334.0-377.0
Tens. str. × 10^3 lb./sq.in.	8.4-8.8	8.68-8.8	8.72-8.79	8.78-8.82
Tens. mod. × 10^3 lb./sq.in.	346.0-368.0	370.0-372.0	345.0-354.0	346.0-360.0
Elongation %	105.0-169.5	113.5-144.0	107.0-129.5	131.0-142.0

No apparent change in appearance of specimens after 60 or 120 days immersion. Specimens darkened after 180 days immersion.

Fuel Oil, Navy Special

Immersion days	0	60	120	180
Dim. change %				
length		neg.	neg.	0-+0.1
width		+0.2-+0.4	−0.2-+0.6	+0.2-+1.0
thickness		0-+0.4	0-+0.4	+0.4-+0.8
Change in wt. %		+0.1	+0.4	+0.1
Change in vol. %		+0.1-+0.7	−0.1-+0.6	+0.5-+1.8
Hardness (Rockwell)	M61-M63	M63-M65	M62-M64	M65-M66
Flex. str.* × 10^3 lb./sq.in.	14.1-14.8	10.0-10.4	7.4-8.8	12.2-12.3
Flex. mod. × 10^3 lb./sq.in.	379.0-420.0	341.0-346.0	311.0-314.0	382.0-404.0
Tens. str. × 10^3 lb./sq.in.	8.4-8.8	8.82-8.94	8.68-8.78	8.84-9.5
Tens. mod. × 10^3 lb./sq.in.	346.0-368.0	364.0-374.0	355.0-366.0	341.0-381.0
Elongation %	105.-169.5	112.0-135.0	100.0-135.5	115.0-141.0

No apparent change in appearance of specimens after immersion.

* Specimens did not break. Flexural strength values computed from maximum loading during bending.

a theoretical phenomenon. The term *unplasticized* PVC is used in this paper, however, because it is much more specific and restrictive than *rigid* PVC. Commercial unplasticized PVC may be considered as a compound of polyvinyl chloride resin in which only the minimum amount of internal lubricant, colorant, and stabilizer for processing stability is used. The optimum physical and chemical properties are obtained in unplasticized PVC.

Rigid PVC is the term applied to compounds which are substantially resin and stabilizer to which modifying resins, rubbers, fillers, and often small amounts of plasticizers have been added. These modifications are usually made to improve processing properties or for the improvement of impact resistance. The processing aids or modifiers, added to the pure PVC resin, whether in polymerization or in subsequent compounding, will reduce the intermolecular attractive forces of the polyvinyl chloride and change the physical and chemical properties from those of the pure resin. Rigid PVC usually has a lower heat distortion point and lower chemical resistivity than un-

Table 5.—Years of Satisfactory Service

HCl
6-in. piping handling HCl gas—outdoors .. 5
2½-in. pipe line, conc. HCl—outdoors, HCl prod. unit 17
20-in. duct, 300 ft. long; HCl gas—outdoors, HCl prod. unit 10
3-in. piping and valves, HCl prod. unit outdoors 10
3-in. piping, ⅛-in. wall valves—200 ft.; HCl prod. unit—outdoors 3
22 be' at 140° F. (gas and aqueous)
4-in. piping, 3/16-in. wall, 500 ft., HCl prod. unit—All outdoors, temp. @ 140° F. 3
500 cu.ft. tank handling 10% HCl 2

H_2SO_4
Exhaust vent. for gas—12,000 cu.m./min... 7
60-ft. high cooling tower—outdoors 5
Storage tank, 15% H_2SO_4 13
Piping and duct work in H_2SO_4 prod. unit. 13
Piping, duct work, and ventilator fans—H_2SO_4 prod. plant 13

HNO_3
Exhaust vents, for gas, 12,000 cu.m./min. ... 7
Storage tank—pickling acid—HNO_3, H_2SO_4 and HF 13
260-ft. stack, 20-in. diam. for gas 1½
100-ft., 3-ft. diam. duct work—HNO_3, prod. plant 1½
Tank 10 ft. high handling fuming HNO_3 .. 5

Cl_2
Gas at 158° F.—2-in. pipe, 3/16-in. wall.. 4
20% destroyed (sl. attack)
20-ft. high chlorination col. (¼-in. sheet).. 1
12-in. chlorination column 2

H_2O_2
Rotary filter 6 ft. × 8 ft. 4
350-cu.ft. tank, 50% H_2O_2 ..... 1½

HF Gas
3-ft. diam. duct work ⅜-in. thick, 100 ft. long ..... Being installed

SO_2 gas
Piping and valves, 3-in. diam. 5

NaOH
Piping and valves 2

Phthalic and Maleic Anhydride
Piping, ventilator fans in prod. plant 2

Drain pipes and gutters 7

Textile industry
1000-ft. piping dil. H_2SO_4 1
Pulley—6-in. diam., ⅛-in. cover dil. H_2SO_4 (6 of 60,000 failed) 3
100 ft. × 9 ft. × 5 ft. tanks—dil. H_2SO_4 at 140° F. 4

Chemical laboratories
Sinks, piping, hoods, duct work 4-10

Food industry
Wine—piping 6
Brewery—piping 4
Vinegar—piping 10
Milk—piping 6
Sugar factories—containers for ion exchange resins 3

Leather tanning
Piping and containers 4

Paper production
Tanks and piping 4

Water treatment
Chlorination tanks and piping 3
Containers for ion exchange resins 3

Soap industry
Soap storage tank 4

Pharmaceutical chem. mfg.
Piping, duct work 2-6

Organic color mfg.
Piping, duct work 6

Agricultural chemicals
Piping, ventilator fans 2-6

Oil refineries
Piping 3-6
Utensils for handling chemicals 3-10

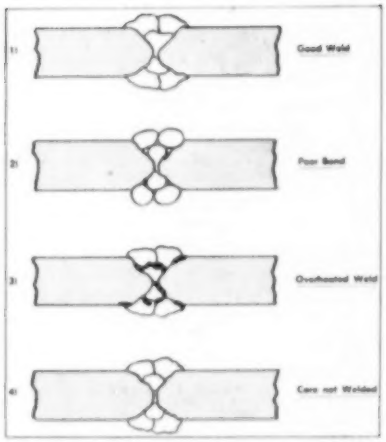


Fig. 5. Correct and incorrect methods of welding.

Fig. 6. Vacuum forming shallow draw mold.

plasticized polyvinyl chloride.

A listing of the chemical resistance of unplasticized PVC toward organic and aqueous inorganic materials appears in Table 3. Most aldehydes, ketones, esters, ethers, and chlorinated hydrocarbons will attack unplasticized PVC readily, as indicated by severe swelling. Other reagents cause less severe swelling but subsequent lowering of physical properties (Figures 1 and 2). Long-chain hydrocarbons and high-hydroxyl-content compounds have little or no effect on the unplasticized polyvinyl chloride. It can generally be said that resistance decreases with heat especially above 160° F. (Figure 3). Data for Figures 1, 2, 3, 10, and 12 through 15, are the results of test performances on Vinidur, the trade name of UPVC manufactured by Badische Anilin & Soda Fabrik, Ludwigshafen, Germany.

Because it is very difficult to duplicate the actual conditions of some specific process, especially if borderline resistance may be expected, samples of unplasticized PVC should be placed in the corrosive media for long contact. This is the most positive method of evaluation in cases where there may be some doubt as to whether unplasticized PVC is the proper material for a specific application.

The form of corrosive attack is penetration of the corrosive liquid or gas into the interior of the material rather than a chemical reaction with the surface. Polyvinyl chloride, like most other plastic materials, shows a weight increase in direct proportion to accompanying volume increase or swelling. (Figure 4.) The swelling caused by aqueous reagents is normally low. The effect of some typical corrosive agents on physical properties may be seen in Table 4.

In addition to temperature, the concentration of aqueous solutions is of great importance. Generally, the damaging effect of aqueous solutions decreases with increasing concentration of such solutions. Figures 12 through 16 show the effect of temperature and concentration on European emulsion polymerized PVC. American suspension polymerized resins may be expected to have a higher chemical resistance.

Other factors influencing chemical resistance must also be considered:

1. Light promotes swelling and surface cracking, especially when plastic approaches decomposition.
2. Overstepping the softening point usually accelerates chemical distortion.
3. Strains and stresses (outside and inside) promote chemical distortion.
4. Pressure accelerates swelling.
5. Local swelling usually leads to cracking.

The diminishing corrosive effect with increasing concentration applies generally to all acids except for those strongly oxidizing acids where beyond a certain concentration a chemical reaction takes place between the acid and the polyvinyl chloride.

Unplasticized polyvinyl chloride should meet a group of tests to establish how well the converter has processed the basic material. The divisions of material types are based on the processing equipment used and on the physical incongruities peculiar to the extruder, calender, laminating press, and transfer mold. These divisions may be established as follows:

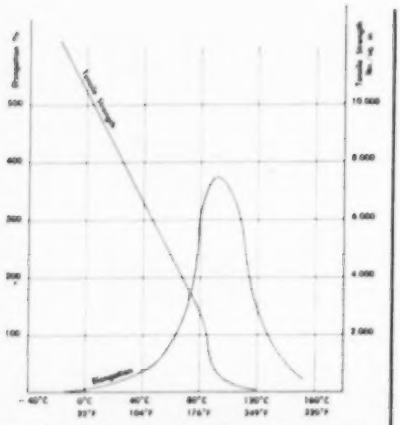


Fig. 7. UPVC tensile strength and elongation vs. temperature.

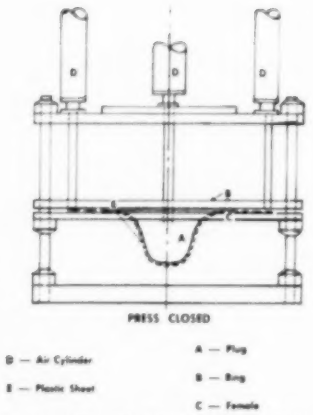


Fig. 8. Plug- and ring-type draw mold.

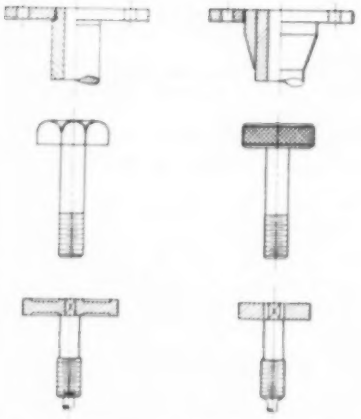
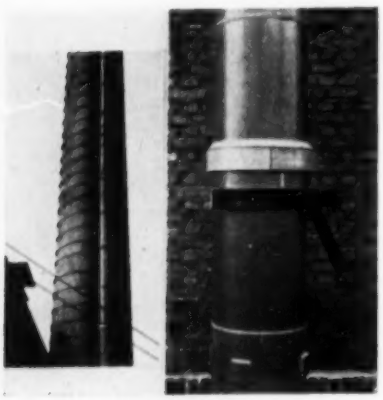


Fig. 9. Correct (right) and incorrect (left) design.



Stock details.

Extruded and Molded Parts

1. **Brittleness**

A hammer blow on material held firmly in a vise should not result in shattering like that of glass.

2. **Homogeneity**

Immersion in anhydrous acetone for several days should result only in swelling with no evidences of cracks, bubbles, separations or porosity.

Pipes and Tubes

1. **Brittleness**

It should be possible to flare the end of the wall of the tube or pipe with a flaring tool with no evidence of brittleness.

2. **Homogeneity**

Immersion in anhydrous acetone for several days should result only in swelling with no evidence of cracks, bubbles, separations, or porosity.

Laminated Sheets

1. **Brittleness-bending**

A strip of a laminated sheet should submit to repeated bending without cracking at room temperature.

There should be no evidence of excessive brittleness when the sheet is struck with a hammer.

2. **Homogeneity or bonding strength**

Hammer blow and knife test

Continuous delamination should not be possible with a hammer and chisel.

Oven and hot gas gun tests

A sheet should not delaminate or blister when subjected to 320° F. for 15 min. in steam oven or when subjected to blast from hot-air gun at approximately 500° F.

Acetone test

A sheet should not show evidence of delamination after 1 to 2 hr. immersion in anhydrous acetone at room temperature.

Closely related to the chemical structure of thermoplastics and polyvinyl chloride is the property of heat fusibility and weldability.

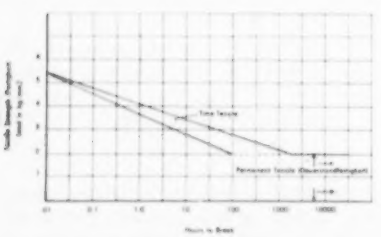


Fig. 10. Permanent tensile strength of unplasticized PVC.

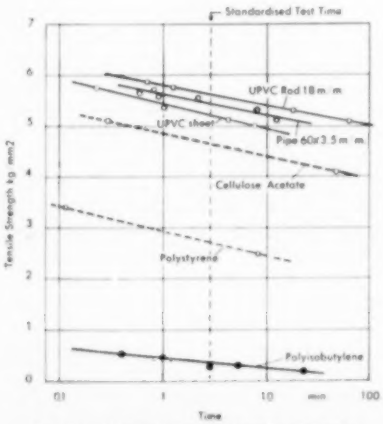


Fig. 11. Effect of time on tensile strength of various plastics.

The method of fabrication offering the widest range of applications and extending the possible size of installations almost infinitely is that of hot-gas welding. The present day hot-gas welding torch consists of a coiled tube heated by a gas flame or a resistance coil, through which passes the compressed air, nitrogen or carbon dioxide. By changing the size of the flame or the velocity of the inert gas, the temperature of the issuing hot gases may be varied over a wide range, 475° F. to 550° F. being normally used.

The preparation of UPVC for welding is essentially the same as for metals. The basic difference is in the type of joining which takes place. Complete fusion of rod and stock takes place in metal welding, but in thermoplastic welding there is a simple bonding between the contacting surfaces of rod and stock. A slight pressure applied to the rod forces the two melted surfaces together and produces a homogeneous weld.

For uniformly good welding the area to be welded as well as the rod must be preheated. Too little heat results in a poor bond; overheating may cause decomposition.

When proper techniques are followed, weld values are normally 85% of the

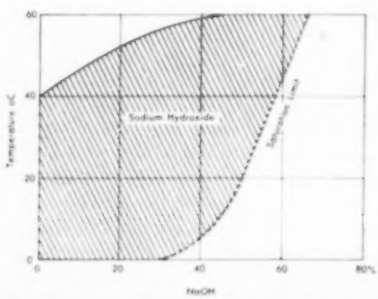


Fig. 12. Chemical resistance limits of PVC to sodium hydroxide (temperature vs. concentration).

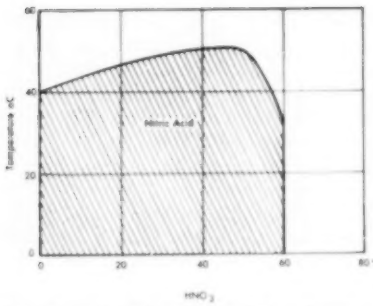


Fig. 13. Chemical resistance limits of PVC to nitric acid (temperature vs. concentration).

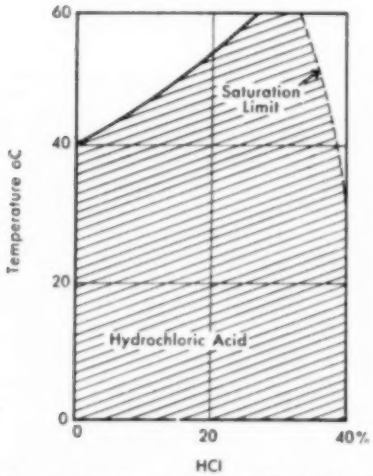


Fig. 14. Chemical resistance limits of PVC to hydrochloric acid (temperature vs. concentration).

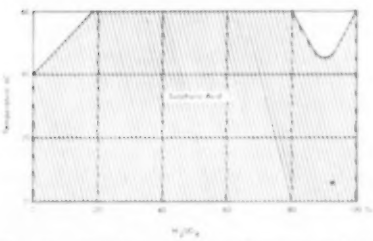
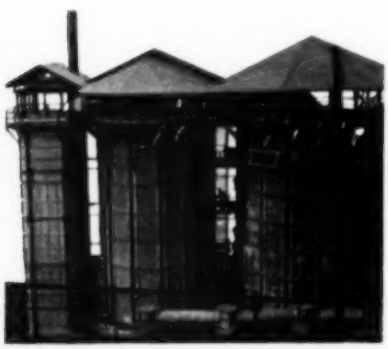


Fig. 15. Chemical resistance limits of PVC to sulfuric acid (temperature vs. concentration).



Cooling towers in rayon processing plant.

tensile value of the base material, and often greater than that of the sheet. The impact strength in the vicinity of the weld is reduced.

Proper welding is the most important element of fabrication. An intensive training course is necessary for plastic welders. The metal welder's hand is too heavy and only a few of his habitual techniques are useful, but his experience will quickly prove invaluable. On the other hand, a person with proper aptitude and training but no familiarity with metal welding should develop into a good plastic welder. It is generally believed that women will prove better suited than men to the continuous, accurate, and delicate routine operation of plastic welding.

The performance of each plastic welder must be checked periodically. Physical tests of sample specimens are the most positive method of arresting the development of bad practices and substandard weld values.

Hot gas welding is used to such a great extent by the fabricator that its influence on the merit of an installation cannot be overemphasized. The raw stock which the fabricator uses must first of all be capable of a good weld. Some high molecular weight PVC resins cannot be welded unless the resin and the welding spline have been modified although such changes are to the detriment of other equally important properties. The use of such PVC compounds is to be avoided. Once the basic weldability of a material has been determined, the fabricator must be aware of the following rules in all subsequent work:

1. The design of the weld should conform to the recommended illustrations (Figure 5) and the conceptions of stress distribution.

2. The surfaces to be welded should be clean and smooth but not polished.

3. The amount of heat applied by the welding gun should be uniform along the length of the weld, and it must be sufficient to effect melting of the rod surface and softening of the rod and melting of the weld-bed surfaces without localized decomposition.

4. A uniform pressure must be maintained on the welding rod at right angles to the plane of the weld to insure intimate contact between the melted surfaces of the rod and the bed.

5. The utmost uniformity should be sought in a weld. Waviness along the weld and elongation of the rod must be avoided.

6. The fewest rods possible should be laid in a single bed because each weld increases the danger of strains and overheating with subsequent weakening of the complete weld.

7. If an error is made in the course of a weld, work should be stopped and the faulty area scraped out and replaced by a properly laid bead.

The Welding Committee of the Thermoplastics Structures Division of the Society of the Plastics Industry has completed the draft of a method for determining welding performance of polyvinyl chloride. The National Bureau of Standards is reviewing the draft and A.S.T.M. is expected to accept it soon.

Friction welding is an additional method of joining. In this process two pieces of material are mounted in a high speed lathe. High frictional heat is generated at the interfaces as one piece is rotated at high speed against the stationary part. This heat fusion requires only a few seconds, and an automatic clutch disengages the parts at the moment of fusion. A strong homogeneous weld is obtained.

Cementing is employed alone or in conjunction with hot-gas welding in tank linings, but principally to effect pipe connections which are completely pressuretight. Depending upon principal requirements such as optimum chemical resistance or optimum impact resistance, cements of vinyl resin solution, post-chlorinated vinyl, or flexible rubber-base are used.

Unplasticized polyvinyl chloride may be shaped by slight modifications of the common forming techniques used in the plastic industry. Shallow forming may be effected on thin sheets by the vacuum method illustrated in Figure 6. The molds may be made inexpensively of wood, masonite, or aluminum. A vacuum of 17 to 25 in. of mercury is sufficient to mold sheets up to ⅛ in. thickness. The material is heated in an oven and is then quickly placed on the mold (cf. Elong./temp. curve Figure 7). A sealing frame is lowered and, the vacuum is applied. This suction is maintained until the stock cools somewhat, and then the molded piece is removed and after complete cooling is trimmed on a saw, router, or shear.

The preferred forming temperature for unplasticized PVC is 130° C. For deep drawing, high forming speeds and lower temperatures are necessary. The deepest draws are possible at approximately 90° C. Heating should proceed evenly without local overheating. This is best accomplished by maintaining the heating media at a moderate temperature differential. The molding process should be completed as quickly as possible and the piece cooled immediately. The importance of this can be shown by leaving a warm piece under stress. Cracking usually results.

Where moldings are made of thicker materials or where deeper draws or sharp curves are required, the plug and ring mold illustrated in Figure 8

may be used. The sheet heated as in vacuum molding, is placed in the mold. The forming plug is lowered until the pressure ring grips the sheet edges. The plug then continues downward pressing the sheet into the mold contour. The material has an elastic memory, i.e., bent sections have a tendency to return to their original shape if reheated. It is essential, therefore, to keep formed parts rigidly clamped in the forming jig until completely cooled.

For intricate shapes and heavy cross sections, the compression and transfer molding methods are followed. Pipe fittings and similar parts are produced by this method. Weighed charges of unplasticized polyvinyl chloride are preheated, preferably electronically, and then placed in the transfer pot or cylinder. The transfer piston moves downward under pressure and forces the hot material through an orifice into the hot steel mold. The mold is then cooled and the piece is removed. Because of high mold costs, this method of fabrication is usually used in making those shapes which are complex and which are used in great quantities.

In the machining of unplasticized PVC, care should be taken to avoid sharp changes in cross section. Also to be avoided is drilling or grooving in areas of critical stress. Parts should not be force-fit if there is an alternative. If proper consideration is given the design and shaping of machined parts, their service life will more than compensate for the time so spent (Figure 9).

Since polyvinyl chloride has no true melting point and since the viscosity of the unplasticized material, even at the softening temperature, is very high, the development of injection molded pipe fittings, valve parts, etc., has been most difficult. However, fittings and various corrosion resistant parts are now being molded by this method, in some cases without auxiliary equipment.

Tensile and elongation figures are of little value without information concerning the stress time to which the test specimen was subjected. When a test specimen is subjected to a permanent medium stress, days or even weeks may pass before a piece suddenly cracks or breaks. That means that the time limit of the particular stress was reached and overstepped. Such breaks often take place without visible deformation, especially when the surface is dented or scratched. This makes it difficult to predict such a break by visual inspection. Before the relationship of time, stress, and break was clearly established, these breaks were explained by local embrittled areas in the material, especially in improperly dimensioned pressure pipes, tight screw joints, and places subjected to strain. There are really no embrittled areas in the material. The piece breaks or cracks because the normal life period at a certain stress has expired. The relationship of time and break strength is easily observed in Figure 11.

Notches or dents may cause breaks without elongation. If comparative elongation tests are made, it is essential that the surface of test specimens be in perfect condition. Short time (3 min.) break strength is seldom considered in practical calculations of maximum allowable stress. Short time tensile should be used only for comparative testing, for example, production control.

To obtain ultimate serviceability from PVC subjected to a continuous permanent strain, the time-stress resistance lines should be used as a guide to product design. Here the following questions arise: Does the resistance-decrease stop after a certain period of time; in other words, does the time-resistance line reach a point where it flattens out? Is there a permanent resistance reached where the time factor is excluded? Is there besides time resistance also a permanent resistance?

Decrease of the stress-time-resistance curve levels off after approximately 1000 to 2000 hr. and a permanent stress resistance takes place. (This may be seen in the curve of Figure 10.) A piece of plastic may be subjected to the permanent stress resistance as long as desired without fear that a crack or break may occur. At room temperature the permanent stress resistance is approximately ⅓ to ½ of the short time (3 min.) break strength. As temperature goes up, tensile strength goes down. The behavior of plastics in this aspect is similar to that of metals, especially those with a high melting point. A property change that takes place in steel at a temperature range of 500° C. (light metals in the range of 150° C.) would take place in plastics at a 50° C. range. The stress resistance of plastics decreases as temperatures go up. For most plastics this curve forms a straight line. As temperatures go down, under room temperature, tensile strength increases.

The opposite takes place with elongation. At higher temperatures thermoplastics are softer and tougher, and at low temperatures harder and more brittle. Short time stress resistance is less influenced by temperatures than is time stress resistance. Permanent stress resistance is influenced by temperature to the greatest extent.

Throughout this paper there may seemingly have been an overemphasis on the problematical features of unplasticized polyvinyl chloride. In the United States it is a relatively new structural material, and only an awareness of its limitations as well as its capabilities can prevent errors of application and assure its promising future. There has been no long-term testing of domestic unplasticized polyvinyl chloride because it has been made here for only a few years.

In Europe, however, fabrications of unplasticized PVC have given satisfactory service for many years, as shown in Table 5. The utilization of unplasticized PVC throughout the whole of the European chemical industry has expanded rapidly since 1946. For example, at the Badische Anilin & Soda Fabrik (B.A.S.F.) in Ludwigshafen, Germany, unplasticized PVC is specified in all places where structural properties permit. Farbenfabriken Bayer has one million pounds of unplasticized PVC in corrosion installations at its Leverkusen, Germany, plant.

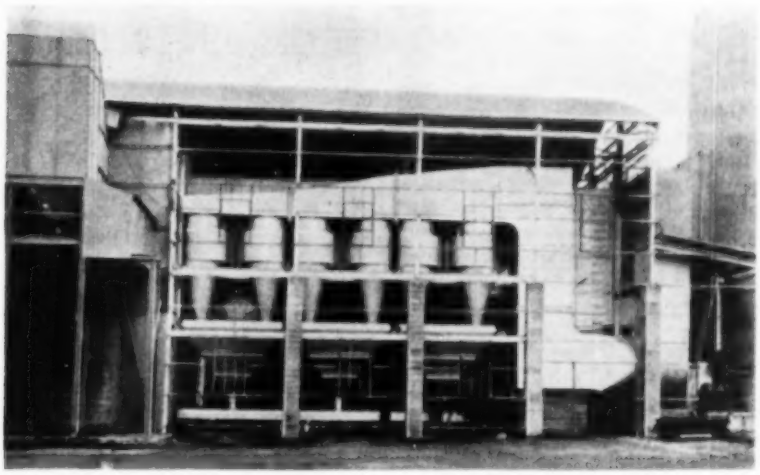
The question, "Can plastics be used in place of metal?" can be answered, "Yes." The question, "Should plastics be used in place of metals?" must be answered "No." Plastics should not be substitutes for metal. Their special properties should be utilized wherever with safety economic advantages can be expected. To this end, the Society of Plastics Industry and the basic raw materials-producers, converters, and fabricators, are conducting at the Battelle Institute, American Gas Association, American Petroleum Institute and the National Sanitation Foundation, Department of Public Health, University of Michigan joint studies of the physical and chemical behavior and toxicological aspects.

Today the United States has surpassed all other countries in the production of plastics, not because it lacks the classical materials which were used before, but because of the conviction that new and better materials have been created. Just how rapid the utilization of unplasticized PVC will be in the United States is dependent upon its early recognition and acceptance by our construction and chemical engineers as an excellent corrosion resistant material.

Acknowledgment is herewith expressed to the following: Badische Anilin and Soda Fabrik, Ludwigshafen a/Rhein, Germany; W. Krannich, "Kunststoffe im Technischen Korrosions—Schutz" Carl Hanser Verlag (1949) (Figs. 1-5, 9-15); H. N. Hartwell & Son, Inc., Boston, Mass.; Industrial Plastics Fabricators, Norwood, Mass.; B. F. Goodrich Chemical Co. (Table 5), Cleveland, Ohio; North Carolina State College of the University of North Carolina, Department of Chemical Engineering (Tables 4), Raleigh, N. C.

Elements of Dust and Mist Collection

C. E. Lapple Ohio State University, Columbus



(*Courtesy Buell Engineering Co.*)

a. Cement plant cyclone installation.

Dust and mist collection is a subject of growing importance owing to the increased interest being shown in the use of techniques to reduce atmospheric contamination. In this paper, which is the first of a series, author Lapple defines the basic considerations to be met by any system, presently available or to be developed.

The author is associate professor of chemical engineering at Ohio State University. He spent thirteen years with Du Pont, most of which time he was a member of what is now the Engineering Research Laboratory, specializing in the field of fluid and particle mechanics (dust collection, atmospheric pollution abatement, size classification, and fluids handling). He is currently active as an industrial consultant in this field and is the author of the *Dust and Mist Collection* section in Perry's "Chemical Engineers' Handbook," and editor and author of a text "Fluid and Particle Mechanics." In 1946 he was the recipient of the A.I.Ch.E. Junior Award. Professor Lapple received his B.S. and Ch.E. degrees at Columbia University in 1936 and 1937, respectively.

In many processes of the chemical industry the removal or collection of dusts and mists has long been an important auxiliary operation; in fact, in some processing operations, such as spray drying, this auxiliary step often is more difficult and critical than the primary one of drying. Only in recent years, however, has this operation received widespread consideration and evaluation, because of sudden public awareness of air pollution, to which dusts and mists are important contributors.

In general, dust and mist collection is concerned with the physical separation of particles, either solid or liquid, from the gas in which they are suspended. Such separation is required for one or more of the following purposes:

A. Recovery of particulates
   1. To collect a product which has been processed or handled in gas suspension, as in spray drying or pneumatic conveying.
   2. To recover a valuable product which has inadvertently become mixed with processing gases, as in kiln or smelter exhausts.

B. Reduction of particulate concentration.
   1. To eliminate a nuisance, as in fly-ash removal.
   2. To reduce equipment maintenance, as in engine intake-air filters.
   3. To eliminate a health, fire, explosion, or safety hazard such as may exist around flour-bagging operations or in exhaust gases containing traces of radioactive particles.
   4. To improve product quality, as in the cleaning of air used in processing pharmaceutical or photographic products.

The achievement of these objectives involves primarily gas-handling equipment, but the design of such equipment must be concerned with the properties and relative amounts of the suspended particles as well as with those of the gas being handled.

This paper will summarize from the viewpoint of the plant or design engineer

Table 1.—Types of Dust- and Mist-Collection Equipment

- Gravity settling chamber
  - Simple
  - Howard
- Inertial separators
  - Impingement
  - Cyclone
  - Mechanical centrifugal
  - Miscellaneous
- Packed beds (fine, coarse; granular, fibrous)
- Cloth collectors
  - Baghouse
  - Unit
  - Mechanical
  - Automatic
- Scrubbers
  - Chamber
  - Cyclonic
  - Inertial
  - Mechanical
  - Packed
  - Film
  - Miscellaneous
- Electrical precipitators
  - Single stage
  - Two stage
  - A.C.
- Air filters
  - Viscous
  - Dry
  - Automatic
  - Miscellaneous (wetted cells, electrostatic, pipe line, activated carbon)
- Miscellaneous
  - Sonic
  - Thermal

(1) the known types of collection equipment, (2) the type, procurement, and utilization of information necessary for proper selection and design of dust- and mist-collection equipment, and, (3) the available reference sources that may be consulted for specific details.

Types of Equipment

In order to separate suspended particles from a gas it is necessary to provide (1) a force which will act on the particle and/or gas to cause a differential motion of the particle relative to the gas, (2) a collecting surface upon which the migrating particle can deposit, (3) sufficient gas retention to permit the particle to migrate to the collecting surface, and (4) a means for removing the deposited particle from the collecting surface and/or the equipment. The known forces which can produce the necessary relative motion between a suspended particle and the gas may be classified as gravitational, inertial, physical or barrier, electrostatic, molecular or diffusional, and thermal or radiant. There are also other mechanisms which can be used to modify the properties of the particles and/or the gas to increase the separating effectiveness of any applied force. Two such mechanisms may be designated as physicochemical and sonic. The former involves such phenomena as condensation of vapors on the particles, alteration of the adhesive forces between particles or between particles and collecting surfaces, evaporation and condensation of small particles onto larger ones, etc., all of which are associated with the physical and chemical properties of the particles and the gas. The sonic mechanism involves flocculation of particles by the physical action of a sonic vibration in the suspending gas to convert small individual suspended particles into larger flocs.

A mechanistic classification is not always convenient, however, because more than one type of force or mechanism may be utilized. Table 1 therefore presents a summary of known types of dust-collection equipment classified according to structural or application similarities.

GRAVITY SETTLING CHAMBER

A gravity settling chamber is simply a compartment in which the velocity of the gas is reduced to permit particles to settle out under the action of gravity. Vertical partitions or baffles serve little useful purpose, but closely spaced horizontal shelves have been utilized to secure a marked improvement in collection efficiency in a modification known as a Howard dust chamber.

INERTIAL DEVICES

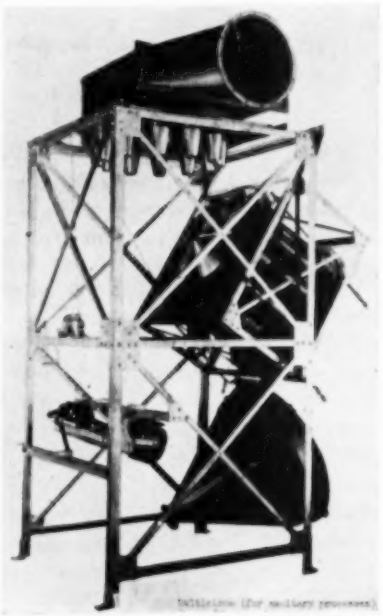
Inertial devices, which include such units as impingement separators, cyclone separators, and mechanical centrifugal separators, depend for their action on the greater inertia of the particles as compared to that of the gas. In impingement separators the dust-laden gas stream is passed around or through fixed elements interposed in the gas stream, the particles being deposited on these elements. In cyclone separators the gas enters a conical or cylindrical chamber tangentially and leaves axially. The resulting centrifugal field causes the suspended particles to migrate to the outermost walls, from which they are led into a receiving bin, hopper, or conveyer. The cyclone represents one of the most widely used and least expensive types of dust collectors. A large variety of makes and configurations is available. For large gas-handling capacities an arrangement of multiple small-diameter cyclones in parallel is often used to attain higher collection efficiency and to reduce headroom requirements. Mechanical centrifugal units are similar to cyclones except that the centrifugal field is provided by a rotating member. Some such units are designed to act as fans for the system in addition to their dust-collection functions. There is a large variety of miscellaneous inertial separators varying in complexity from a simple gas-reversal chamber to a rotary unit employing closely spaced sinusoidal plates. Most steam or compressed-air entrainment separators fall into this category.

(Courtesy Pratt-Daniel Corp.)

b. Multicyclone.

PACKED BEDS

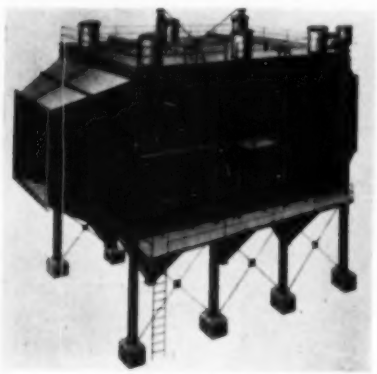
Packed beds are units in which the dust-laden gas stream is passed through a bed or layer of packing, which may be granular materials such as sand, coke, gravel, or Raschig rings or fibrous materials such as glass wool, steel wool, or



(Courtesy Western Precipitation Corp.)

c. Multiclone for sanitary processes.

textile staples. Depending on the application and type of packing, bed depths may range from a small fraction of an inch to several feet. The coarser packings, which are used at relatively high throughput rates (1 to 15 ft./sec. superficial velocity) to remove the coarser suspended particles, rely primarily upon inertial effects for the deposition mechanism. The finer packings, which are operated at lower throughput rates (1 to 30 ft./min. superficial velocity) for removing relatively small suspended particles, usually utilize the physical or barrier, diffusional, and gravity settling mechanisms at the lower velocities and inertial mechanisms at the higher velocities. In some units electrostatic effects may play a significant role. Packed beds are usually limited to collecting mists or dusts at low concentration because of gradual plugging due to dust accumulation, unless some provision is made for removing the dust, as by periodic or continuous withdrawal of part of the packing for cleaning.



(Courtesy Koppers Co., Inc.)

d. Electrical precipitator.

CLOTH COLLECTORS

In cloth collectors the gas is passed through a woven or felted fabric upon which the gradual deposition of dust forms a precoat, which then serves as a filter for the subsequent dust. These units are analogous to those used in liquid filtration. Cloth collectors range from the old-fashioned baghouse, a separate building in which large bags were suspended, to the heavy-duty units with automatic gas cut-off valves and bag shaking or cleaning at timed intervals. Although a wide variety of filter media is available, these units are not usually applicable for high-temperature work. Cotton or wool sateens or felts are commonly used. Orlon acrylic fiber permits application at temperatures up to 300° F. Glass and asbestos or combinations thereof have been used for temperatures up to 650° F. but have not been satisfactory because of excessive bag failures. For very small capacities metallic screens have been used successfully for temperatures up to 1,000° F. Porous ceramic and stainless steel have also been employed for high-temperature applications.

SCRUBBERS

Scrubbers comprise all units in which a liquid, usually water, is used to assist in the particulate collection process. An extremely wide variety of equipment is available in this category, ranging from simple modifications of corresponding dry units to permit liquid addition to those specifically designed for wet operation only. When properly designed or selected for a particular application, scrubbers can give very high collection efficiencies. The mere addition of water to a gas stream, however, is not necessarily effective.

ELECTRICAL PRECIPITATORS

In electrical precipitators dust or mist particles, electrically charged by means of a corona, migrate to a collecting surface. The single-stage unit, commonly known as a Cottrell precipitator in which the charging and collection steps are carried out simultaneously, is the type generally used for industrial or process applications. The two-stage unit, in which the two steps are carried out successively, is commonly used for air-conditioning work although some industrial applications have been made. The single-stage units normally employ direct current at voltages in the range of 30,000 to 100,000; two-stage units used in air conditioning employ direct current at voltages ranging from 5,000 to 13,000 and clearances of ¼ to ½ in. between the collector plates. Alternating current can be used, but the air-handling capacity for effective collection will be markedly lower. Consequently the use of alternating current has been limited to laboratory or sampling applications.

AIR FILTERS

Air filters include all units used in elimination of small quantities of dust from large quantities of air, as in air-conditioning applications. All the devices in this category have been classified separately because of their wide usage and special features. Viscous filters, so named because the filter medium is coated with a viscous oil to retain collected dust, are basically coarse fibrous packed beds operated at high throughput rates. Dry filters are essentially thin, fine fibrous packed beds, similar to cloth collectors but operated at somewhat higher throughput rates. They are usually mounted in a zigzag or pocket arrangement rather than in bag form to achieve space economy. Both viscous and dry filters, known as unit filters, are available from a large number of manufacturers as standard packaged units. These units, 1 to 2 ft. square on the face, are mounted side by side in a frame to provide any desired air-handling capacity. Automatic filters may be of either the dry or viscous type provided with a continuous and automatic cleaning arrangement for use when dealing with relatively dusty atmospheres.

SONIC COLLECTION

In sonic collection acoustic vibrations imparted to the gas stream cause suspended particles to collide and flocculate. The larger flocs are then more readily collected in conventional apparatus. This principle has only recently found industrial usage and is still limited in application.

THERMAL PRECIPITATION

In thermal precipitation suspended particles are caused to migrate toward a cold surface or away from a heated surface by the action of a temperature gradient in the gas stream. This principle, which has been used in sampling work, has not yet found industrial application.

For further descriptive details the reader is referred to illustrations (a-f) and references (*2, 5, 7-9*).

Selection of Equipment

Theoretically it would be possible to use any of the types of equipment listed in Table 1 for any dust- or mist-collection problem, but practical and economic considerations restrict the range of applicability for each type. To select the proper type of equipment for a given application, two questions, what are we dealing with? and what do we want the equipment to do? must be answered. Particle size, particle concentration, and required collection efficiency may be used as the basis for a preliminary selection of equipment. Once a preliminary selection has been made, it is usually possible to narrow the choice by considering other special factors such as high temperature and corrosive conditions. At this stage the choice of a unit for a specific application is usually fairly obvious or is limited to two or three types. Then a final selection should be made on the basis of detailed analyses of design and economy.

Preliminary selection of equipment on the basis of particle size, particle concentration, and required collection efficiency may be aided by a tabular guide which gives an illustrative problem and a comprehensive listing of the other factors which may enter into the selection and design (*7*). Sylvan has recently presented a graphical method for predicting the performance of dust- and mist-collection equipment (*4*).

Design of Equipment

In most types of collection equipment the size of the unit selected will be determined within fairly narrow limits by the gas rate and the gas density. Such factors as required collection efficiency, particle size, and particle concentration may influence the design and are usually predominant in determining the type of unit selected. For many units the collection efficiency for a given dust or mist will be fixed within a relatively narrow range. Mechanical details and auxiliary equipment will be determined by a wide variety of factors (*7*).

Details of available technical information on the design of various types of collection equipment are supplied by Perry (*9*) and by the manufacturers of the units. References (*2*)

Table 2.—Classification and Particle Size Range of Gas Dispersoids

Classification	Approximate particle diameter, μ
Mechanical dispersoid	
Dust	Greater than 1
Spray	Greater than 10
Condensed dispersoid	
Fume	Less than 1
Mist	Less than 10

and (*5*) contain additional technical information, reference *2* having particularly useful data on installation and operating costs. This reference also contains extensive field-performance data. The usefulness of such data is limited, however, to operations closely allied to those for which the test data were obtained since there is no attempt at any generalized coordination of the field data.

The total installed cost of collection equipment may range from $20 to $20,000/(1,000 cu.ft./min.) of gas handled, depending on the size and type of application. In air-conditioning work the total cost is usually in the range of $20 to $200/(1,000 cu.ft./min.); process applications are normally higher by a factor of ten. The significant cost of collection equipment makes it essential that this factor be considered in any new plant design or process development. In such cases it is also well to review the process to determine the possible economies that might be obtained by modifying the process so as to eliminate the necessity for collection equipment. In the case of high capacity operations or especially noxious materials, the question of collection may be a prime factor in determining the plant site or location.

For very large installations or cases where performance is particularly critical or unusual, it is generally advisable, when possible, to precede final design with small-scale field tests after a preliminary discriminating selection of applicable types of units has been made.

Data Procurement

The following paragraphs indicate how facts or estimates of particle size, particle concentration, and required collection efficiency may be obtained.

PARTICLE SIZE

The term *particle size* usually refers to the average or effective diameter of the particle. The most widely used unit of particle size is the micron, μ, defined as 1/1,000 mm.

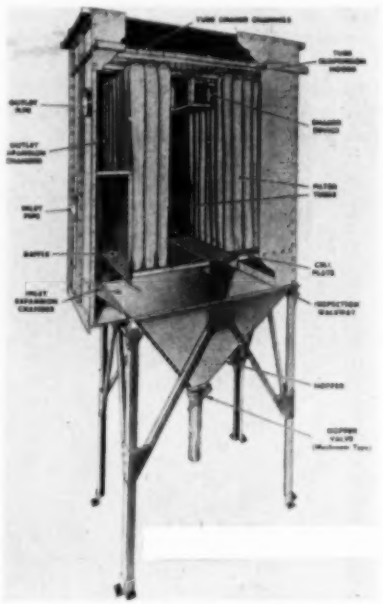
In order to define a particle it is necessary to specify its shape as well as its size. Although most particles encountered in practice are irregular, no satisfactory universal method has yet been devised for assessing particle shape. For practical purposes, it is common to specify particle size as the size of an equivalent sphere where *equivalent* is determined by the method of size analysis employed. Consequently, the purpose of the size analysis must be kept in mind when selecting the method of size analysis.

Dusts and mists found in practice rarely consist of particles of a given size; instead they are composed of a range of sizes. Therefore, in addition to an average size, it becomes necessary to specify size distribution or the relative amounts of each size present. Where a wide distribution of sizes is involved, as is usually the case, the term *average size* can have a variety of meanings depending on the definition employed. In most process applications it has been customary to specify average size on a weight basis such that half of the particles by weight are coarser than the average size, and the other half finer. In industrial hygiene applications the average diameter is commonly defined in a similar manner except that a number rather than a weight basis is used. For a given dust or mist, the average diameter on a number basis will always be smaller than that on a weight basis and may be smaller by a several fold factor, depending on the size distribution.

For most dust- or mist-collection applications an approximate idea of the particle size range is usually adequate for selection and design of collection equipment. In fact, because of the present technological state of the field, it is generally not possible to utilize quantitatively any accurate particle-size data that may be available. The necessary information may be obtained by microscopic examination of a sample of the dust or mist or by reference to published data on similar processes (*2, 4, 5, 6, 8,* and *9*). Dusts and mists are formed either mechanically, as by comminution, decrepitation, and atomization, or by condensation, as in the condensation of a vapor phase or the result of a vapor-phase reaction. Mechanical dispersoids may be termed *dust* or *spray*, referring to solids and liquids respectively. Condensed dispersoids may be termed *fume* or *mist*, referring to solid and liquid particles respectively. Each of these methods of formation results in particles of a certain predominant size range, as indicated in Table *2*.

Smoke is a term usually applied to a fume or mist formed by combustion. It should be noted that these terms are not standardized and considerable confusion of terminology exists in the literature.

Where it is deemed desirable to make a particle-size analysis of a dust, a variety of methods is available. These methods, which may be classified as sieve, microscopic, elutriation, sedimentation, and miscellaneous, are discussed in more detail in references (*2, 6, 8* and *9*). A recent instrument that offers considerable promise for field analyses is the jet impactor (*2, 7, 8* and *10*). It should be emphasized that most methods of size analysis do not measure particle size; instead they usually measure some other property of the particles which is then converted to an apparent or effective size by means of analytical or empirical relationships. Many of these incorporate various assumptions in order to permit such conversion. Also it cannot be too strongly emphasized that there are many pitfalls in obtaining a reliable particle-size analysis.



(Courtesy American Wheelabrator and Equipment Corp.)

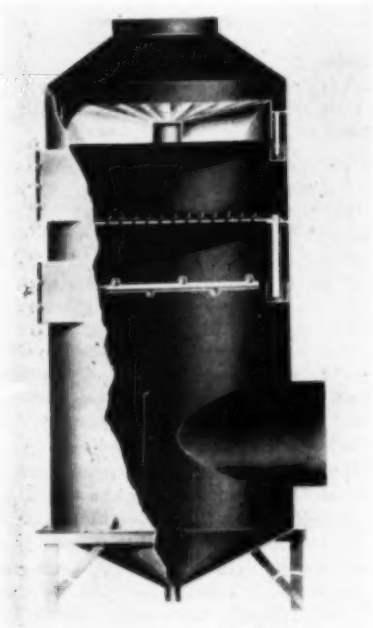
e. Cloth collector.

In practice the particles suspended in a gas stream may be flocculated to a greater or lesser degree; that is, two or more particles adhere together and behave as an effectively single larger particle. This effect will become more pronounced as the dust concentration increases. The various methods of size analysis attempt to measure the ultimate or deflocculated size distribution of a dust or powder since this is the only reproducible state. Thus the effective size distribution in gas suspension may be considerably coarser than the size analysis would indicate. There are at present no generally reliable ways in which to predict the extent of flocculation. Some semiquantitative measure of the extent of flocculation may be obtained by inserting devices such as a cyclone, set-

tling chamber, or coarse-fiber bed into the sampling lines to act as crude classifiers. The fraction of material collected by these devices may then be compared with what they might be expected to collect if the dust had been dispersed.

DUST OR MIST CONCENTRATION

In the dust-control field the concentration of suspended particles is commonly expressed as grains/cu.ft. of gas, where 7,000 grains = 1 lb. Process dust concentrations normally may range from 0.01 to 100 grains/cu.ft., with 1 to 10 grains/cu.ft. being a common range in process ventilation work. In air-conditioning work the concentration of solids in atmospheric air may range from 0.01 to 10 grains/1,000 cu.ft.; in operations such as pneumatic conveying the concentrations of solid matter in the gas stream may range from 0.1 to 50 lb.



(Courtesy Peabody Engineering Corp.)

f. Peabody scrubber.

solid/lb. gas (about 50 to 20,000 grains/cu.ft.); in a fluidized solid system the concentrations will frequently run over 1,000 lb./lb.; spray concentrations may run up to 100 grains/cu.ft.; and mist concentrations may run as high as 10 grains/cu.ft. Typical concentrations encountered in various industrial operations are given in references (*2*, *3*, and *4*).

If it becomes desirable to make an accurate determination of concentration in any specific application, it will be necessary to resort to field sampling, which involves a procedure similar to gas sampling except that an additional precaution must be taken to avoid segregation or classification of the particles entering the sampling probe. This is done by isokinetic sampling, that is, maintaining the velocity at the inlet to the sampling probe the same as the velocity of the gas in the duct at that point (*1*, *2*, *6*, *7*, *9*, *11*, and *12*). If most of the suspended matter is smaller than a few microns, segregation effects are usually negligible and isokinetic conditions are not normally necessary for obtaining representative samples. A traverse of the duct must usually be made to allow for possible segregation of particles within the duct.

COLLECTION EFFICIENCY

In all cases the function of installing dust-or mist-collection equipment is one of reducing exhaust-gas particle concentrations to some predetermined level. This is essentially true whether the purpose of collection is one of recovery economics or one of reducing effluent concentrations to a tolerable limit. It is for this reason that some prefer to assess equipment performance in terms of outlet dust concentration. For a given equipment, particulate, and operating condition, outlet particulate concentration will usually be a function of inlet concentration. Collection efficiency, defined as the weight percentage of entering particles collected, is, however, a more nearly characteristic measure of equipment performance under these conditions.

To determine required collection efficiency, it is usually necessary to calculate it from estimates of inlet concentrations and desired outlet concentrations. The following discussion will deal with methods for estimating desired outlet concentrations since inlet concentrations have been dealt with previously.

Where the annual loss of particulate values from a system is less than ($200/year)/(1,000 cu.ft./min.) of gas handled, collection usually cannot be justified on an economic basis alone. When the purpose of installing collection equipment is reduction of particulate concentration for other than economic reasons, required collection efficiency is more difficult to assess. Sometimes legislative requirements will afford a direct basis, and in other cases known tolerance limits may be applied directly. In cases of atmospheric pollution it may be possible to estimate permissible stack concentrations from known tolerance limits at ground level (*7*) and stack dilution effects as determined for local meteorological conditions.

Trends

Until a few years ago the practical application of dust and mist collection was concerned, for the most part, with problems involving relatively large particles (over 5μ diam.) present at medium to high concentrations (over 1 grain/cu.ft.). Because of the great current interest in air-pollution abatement, the advent of processes involving more potent contaminants, and the exacting requirements for control of radioactive contaminants, the emphasis in recent investigations has shifted to problems involving very small particles present at relatively low concentrations (less than 1 grain/cu.ft.) with relatively stringent collection-efficiency requirements. The widespread use of fluidized-solids techniques has created a need for basic information on high-capacity collection of high concentrations of solids at very high collection efficiency. This phase appears to have received but scant basic consideration to date. In general, the greatest deterrent to rapid advance in technology in the field of particulates is still the lack of techniques for producing and evaluating the properties of particulates and for evaluating equipment performance. Although numerous techniques have been developed and used, they still lack the combination of rapidity, reliability, and standardization.

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The Chemical Engineer

in the steel industry

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Much is written about chemical engineering in the traditional process industries. Little has appeared, in contrast, about the vital roles many chemical engineers are playing in other industries such as steel. To further an understanding of their participation in lesser known fields, the editors of C.E.P. believe that this paper makes a real contribution.

The urgent necessity for chemical engineers in many industries is an accepted fact. Without the chemical engineer it is impossible to conceive of the amazing strides in the production of new antibiotics, in the development of a myriad of new synthetic chemicals, or in the gradual replacement of natural fibers with their man-made counterparts. The sound basic training of the chemical engineer combined with mental flexibility can now be applied in a new field—the steel industry—a neglected orphan which must be adopted by chemical engineers if it is to continue to improve and grow.

Chemical engineering is essential in the steel industry for many reasons. A thorough understanding of the blast furnace requires a basic knowledge of the flooding concept as applied to a packed column, which a blast furnace actually is. Interestingly, this concept was first proposed by a chemical engineer. Chemical engineering is also required because open hearth is an extraction operation involving distribution of a solute between two immiscible phases, slag and metal. Admittedly the problem is complicated by several simultaneous chemical reactions. Some chemical engineer will undoubtedly resolve many open-hearth problems by successful application of the film theory. Finally, chemical engineering is essential because heat treatment of steel requires a thorough understanding of heat transfer, including the complex problem of unsteady-state heat transfer in irregular shapes. Present knowledge of this field poses many questions which challenge the chemical engineer. This paper will outline in rather broad strokes the general flowsheet of the steel industry from raw material to finished product and point out its essential chemical engineering nature.

Raw Material—A Chemical Problem

The raw material of the steel industry is primarily iron ore. Alarmists write that this country is running out of domestic sources of ore. But such is not the case. The direct-shipping ore presently being depleted comprises only about 3 to 5% of the total iron content of the original taconite formation. This direct shipping ore was formed by natural alteration of the taconite. Extensive research has indicated the feasibility of man-made alteration of the taconite to produce an iron ore which may be considerably better than the natural product. Successful exploitation of the taconite development will probably make available as much synthetic ore as the natural ore used to date in this country by the steel industry.

Present processes for recovering high grade ore from taconite are based on the treatment of that part of the taconite formation in which iron is present as magnetite, Fe_3O_4. Aside from the magnetite, the balance of the taconite is one form or another of silica. All recovery processes so far used are some modification of one general scheme. The taconite is ground fine enough to liberate the magnetite from the matrix, and a slurry of the ground material is passed through a magnetic separator. The tailings containing gangue material are treated by sedimentation, flocculation, and filtration for recovery of water for recirculation. This water economy is essential because, surprisingly enough, water is a scarce commodity in the Minnesota ore country, the ore body being very close to the height of land. The wet magnetite product is then dried to a low moisture content. Because nearly all of the material is less than 100 mesh in size, it must be agglomerated to be useful at the blast furnace. It is indeed significant that the essential steps of

taconite processing—crushing, grinding, sedimentation, flocculation, filtration, and agglomeration—are all common chemical engineering operations.

Blast Furnace—A Packed Column

The blast furnace also presents an interesting field for exploration by chemical engineers. It is essentially a column packed with broken solids—ore, coke and limestone—through which a large volume of air is passed, much as in an absorption column. But the problem is slightly different from the usual case of absorption. Essentially, the stack of the blast furnace, the region above the hearth, serves the purpose of preheating the charge for later smelting and partly reducing the ore with the ascending stream of gas containing carbon monoxide. Heat and the reducing gas are supplied at the base of the stack in the tuyere region by burning the descending coke with a preheated blast of air. This rather simple picture is complicated by other considerations: part way down the stack the limestone is calcined, and the carbon dioxide evolved alters the equilibrium considerations; further down the stack the gangue materials in the ore, essentially alumina and silica combined with lime, melt to produce a rather viscous liquid, known as slag, which may flood the column.

The blast furnace will produce better if more extensive contact between the gas rising from the tuyere region of the furnace and the burden descending through the stack is achieved. Intimate contact in this instance means better heat transfer and greater speed of chemical reactions.

Chemical engineers will agree that poor contact could result from the nonuniform size of materials charged to the furnace. For example, fines lodging in the space between coarse particles can produce a bed relatively impermeable to the rising stream of gases. On the other hand, coarse particles segregated in one region of the stack, can lead to channeling and its concomitant disadvantages. Because the greatest gas flow for a given pressure drop will be achieved in a bed of particles of relatively uniform size, agglomeration procedures are important.

Sizing alone is not the ultimate answer to the problem of gas-solid contact, particularly with respect to agglomerates. The situation is one in which microporosity is at least as important as macroporosity. This is the reason for suspecting that pellets may be better agglomerates than either sinters or nodules, their microporosity or so-called reducibility being much higher. Surely, this is a familiar problem for chemical engineers since it includes the surface active area in a solid, gas diffusivity, and contact between solids and gases with all the accompanying concepts.

The blast furnace involves many other problems to challenge the skill of the chemical engineer. Its stack, for example, serves as a heat exchanger between the gases and solids in the stack. Chemical theory suggests that the addition to the air blast of certain gases such as steam, oxygen or natural gas should enhance the performance of a blast furnace. Practice, however, does not confirm theory perhaps for the following reason. Inasmuch as a number of reactions requiring heat at a given temperature are occurring, it is possible that the temperature gradient both in the solid and in the gas in the furnace is being so drastically altered by these additions as to defeat thermodynamic possibilities. Certain work indicates but by no means proves such a possibility. Calculations are tremendously complex; yet it is conceivable that some chemical engineer using the tools peculiar to his profession will find what, if anything, can be usefully added to the existing gas in a furnace.

A still more fundamental consideration regarding the blast furnace is that of its basic process. The modern furnace, soundly developed step by step from a primitive smelter, is so efficient that it is hard to imagine a competitive scheme. Nonetheless, the American furnace was developed and improved for ore which both physically and chemically has not changed for decades. Now there is a gradual transition from the ores of the past to new sources of iron. Is it not possible that some chemical engineer will find a new smelting scheme more effective than the blast furnace?

Steel Refining—Another Challenge

The refining of steel poses another challenge for the chemical engineer. Basically, it is an oxidation process in which the impurities are oxidized in the order silicon, manganese, phosphorus, and carbon. Oxygen is supplied first by the oxidized scrap and finally by iron ore added to the melt. Silicon is oxidized by combined oxygen in the melt to form silica. Silica, an acid, reacts with iron or manganese oxides to form fusible silicates insoluble in the metal. Hence, a separate phase, slag, is formed. In the presence of the lime which is added during refining, the iron and manganese silicates react to form calcium silicate, a slag constituent, plus iron and manganese oxides. Iron and manganese oxides are soluble in both the slag and the metal. The proportion of each in slag and in metal is governed by the same laws that control the distribution of any solute between two immiscible solvents. Naturally, the oxidation of silicon depletes the supply of iron oxide in the metal, and this deficit of iron oxide in the metal is immediately replenished by withdrawal from the slag as predicted by the distribution law. Needless to say, the slag must always contain an excess of iron oxide to ensure removal of silica. Manganese, phosphorus, and carbon are removed by approximately the same mechanism, although the phenomena are not identical. Unfortunately, the distribution coefficient of manganese oxide is such that most of it reverts to the slag. Perhaps a chemical engineer may find a way to avoid the loss of essential manganese.

The similarity between this steel refining operation and conventional engineering absorption and extraction operations is surprising. It is transfer between phases accompanied by chemical reaction. The reactions do not complicate the case too much because their rates are apparently very high. Admittedly, the temperature levels are much higher than in the usual case, the phases are both opaque, and analytical procedures difficult. But the same approach of more extensive contact between phases and of control of the concentration of reagents should prevail.

Coke Oven Chemicals

For completeness the production of coke and the recovery of coal chemicals should be considered here. But less attention need be given to these because they are already accepted chemical engineering operations. But a challenge to the imagination may exist in coke manufacture. The rate of reaction in coke making is apparently inconsequential; yet it requires 16 to 24 hr. to produce coke in commercial coke ovens. The length of this period is due mainly to the difficulty of transferring heat into a bed of coal approximately 20 in. thick by heating it from both sides. A further handicap is the requirement that the heat be supplied through refractory walls from the combustion of gas. Every particle of the coal must eventually reach a temperature of possibly 2,000° F. and all heat must be supplied by conduction through layers of two materials both having low thermal conductivity. Perhaps some day a chemical engineering expert thoroughly acquainted with the concepts of heat flow and further fortified by the happy trait of mechanical ingenuity will find some better way to do the job.

In the coal chemical field, where processing has followed a familiar pattern for years, a renaissance is apparent. Spectacular advances in the synthetic chemical field supplied the initiative. The coke oven, after all, was the cradle of the benzene ring. But the old staid rather angular character has taken on new luster and some of his more specialized relatives such as naphthalene, pyridine, indene, and anthracene are gaining prominence. This trend had focused much attention on coal chemicals and methods for their recovery and purification. Here the chemical engineer can display to its full extent his portfolio containing azeotropic or extractive distillation; absorption, simple or otherwise; crystallization; and the various catalytic modifications requiring fluidized beds if he wishes. All these can be applied to the problem of producing more varied and purer raw materials and finished products for the glamor fields at the chemical frontier.

Pollution Abatement

The chemical engineer can also make major contributions in the field of pollution abatement. It is becoming increasingly apparent that the chemical engineer is wresting some part if not all of this field from the entrenched professions of civil and sanitary engineering. Quite possibly this is happening because the incumbents have dwelt too long with community sewage disposal to the exclusion of the industrial field. Where the problem results in effluents not too different from sewage, such as in the food industry or in certain organic chemical industries, the veterans seem capable of handling the problems. But in the metallurgical industry the chemical engineer is outstanding.

The air we all breath must also be kept clean. The cost of clean air may far exceed the cost of clean streams. Just as an example, if $500,000 is a fair cost for installing at the open hearth equipment capable of removing essentially all solids from the stack gas, the total cost of similar installations at every open-hearth furnace in Allegheny County, Pennsylvania, would be about $60,000,000 for the steel industry has about 120 such furnaces in the County. For these stakes much research has already been undertaken and much more will be required to establish some less costly means for doing the job. When the chemical engineer has finished with the open hearth, he can adapt his new device to the blast furnace and to the pneumatic refining operations, not to mention the conventional boiler house.

Steel Finishing

Still another field for the chemical engineer is that of steel finishing. While the steel is still molten in the ladle prior to being poured into the ingot mold, additions of various reagents or alloying elements are made. Nearly every addition made is subject to reaction with the metal itself or some other element or compound in the metal. One important class of additives is deoxidizers such as aluminum which remove oxygen from the steel to various degrees and impart specific metallurgical properties. Most deoxidizers produce during reaction finely divided oxides which are not soluble in the steel and accordingly rise to the surface. If prior to solidification the oxides fail to rise from the steel, they become so-called inclusions, which adversely affect certain metallurgical properties of the steel. Methods for decreasing such inclusions involve application of thermodynamic considerations and Stokes' Law. Here we are again in chemical engineering.

Next in the flow-sheet of steel-making operations are the rolling operations by which steel is formed into the various shapes useful for further processing or possibly for the customer. The details of the rolling operation, such as roll design, type of drive, and motive power, should be left to the mechanical engineer, just as the determination of the temperature for rolling should be the task of the metallurgist so that he may meet the required metallurgical specifications in the finished steel. But the chemical engineer can help both by assisting in the job of heating the steel between rolling operations to ensure that it is at the correct temperature and that the oxide produced on its surface is either at a minimum or is very easily removable by simple mechanical devices. Here the solution to the problem involves a thorough knowledge of the field of combustion and flame propagation; heat transfer, particularly the unsteady-state type; and the complicated equilibria existing between various combustion atmospheres and steel at elevated temperatures.

Hot-rolled strip as produced is coated with an oxide which is generally removed by pickling in acid under conditions which involve a nice compromise between rapid solution of oxide without excessive loss of metal. The strip, free of oxide, is then cold reduced to gauges ranging down to 0.010 in. in thickness for most grades of tin plate. During this operation the deformation of the cold steel produces an unduly hard product difficult to fabricate. Such excessive hardness must be reduced. This is done by annealing, that is, by heating the steel to temperatures generally near 1200° F. But annealing involves considerable hazard. The steel surface must be protected as much as possible from harmful oxidation. This means that it must be protected by a relatively inert atmosphere, one which will not react with steel. Furthermore, enough of this gas is required that it must be cheap. Helium, which in other ways might be the most desirable, is far too expensive. Nitrogen, entirely free of oxygen, surprisingly enough is also costly. Accordingly such gases as can be produced by modifying the products of the incomplete combustion of a fuel with air are left. Those familiar with the problem recognize the difficulty of producing in this manner a low-priced gas which will remain relatively inert to steel at temperatures ranging from room temperature to 1200° F. Working out a foolproof gas production unit will tax the ingenuity of a chemical engineer.

After the annealing, the steel strip is temper-rolled to restore to it a controlled measure of the hardness removed during annealing. At this point in the flow sheet a major portion flows to customers, principally the automotive industry. The balance passes on to operations where once again the chemical engineer is in his element. These products are the coated steels—tin plate, galvanized sheet, and the like, for which a variety of very specialized operations is used. Knowledge of electrochemistry and surface chemistry including corrosion are valuable tools for the chemical engineer at this point. The coating operations range from bonderizing, that is, the deposition of a controlled thin layer of phosphates on the surface, to tinning, which involves the deposition of a layer of tin only about 0.00001 of an inch. Bonderizing protects the surface and prepares the surface for painting or enameling and tinning produces the tin plate food containers. The technology of such operations is an entire field in itself and a thorough grounding in chemical engineering is essential.

These coated steels are the ultimate in high grade production and represent the culmination of decades of technical advancement. They are indeed the glamor products of a bread-and-butter industry, and their manufacture is a far cry from the days when steel-making was an art. Technology alone can make such products possible and it is reasonable to expect that the next decade will bring a general acceptance of steel production as one of the important and diverse fields of chemical engineering.

Presented at A.I.Ch.E. St. Louis meeting.

Extraction Design

A graphical method for 4-component processes

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The presentation of quaternary equilibrium data on cartesian coordinates permits well-known graphical methods to be applied directly to liquid-liquid extraction design calculations involving systems of four liquids. Principles underlying such presentation and the application are explained. In contrast to other quaternary calculations this extension of the procedures which have been successfully applied to ternary systems is accomplished without sacrifice of generality, rigor or simplicity. A center-fed process with double solvents is considered and the number of equilibrium stages required for a specified separation is calculated. The effect of varying solvent rates on the total number of stages required is investigated.

For more than twenty years engineers have used graphical methods to simplify equilibrium-stage calculations in the design of liquid-liquid extraction processes (*3, 7, 10*). In theory, extraction design calculations are restricted to ideal stages and are usually confined to isothermal operation. Graphical methods are limited further by the availability and precision of equilibrium data and the ability to perform the graphical calculations accurately. Besides these basic restrictions, graphical methods have generally been limited to extraction processes involving only three liquid components.

The several graphical procedures which have been suggested for the design of processes involving liquid systems of four components are severely restricted in their application. One such method, a direct extension of ternary calculation procedures, requires that the quaternary system can be divided into two independent ternary systems (*1, 8*). Other methods proposed by Hunter (*5*) and J. C. Smith (*9*) can be applied only to single-stage extraction processes. The procedure described by Otero (*6*) can be applied to cascade processes with feed entered in one of the end staged. However, the compositions of all terminal streams must be known and the location of an operating line must be assumed.

The graphical method which is proposed in this article extends design procedures to include quaternary systems without the severe restrictions inherent in previous methods. It can be applied to any two-phase liquid system of four components because of a general method of representing complex equilibrium data. Further the method can be used to design cascade extraction processes of all types because the graphical procedures involve no restrictions other than those basic to any graphical method. As a result, many commercial processes, which previously required direct experimental investigation, can now be designed from fundamental equilibrium data.

Equilibrium Data for Quaternary Systems

Advantages of the proposed graphical method of calculation are due primarily to a convenient presentation of equilibrium data. Therefore, before the actual calculation method can be illustrated, the means of presenting data will be explained.

EQUILIBRIUM SURFACE

One of the problems encountered in making quaternary graphical calculations feasible was the representation of the *equilibrium surface* on a plane. The equilibrium surface is the locus of all points representing compositions of saturated liquids. It is usually presented as a surface enclosed in a regular tetrahedron. For one type of quaternary system, that in which only one pair of liquids is partially immiscible, a typical representation of data appears as the curved surface in Figure 1a. It is often helpful to visualize the equilibrium data in the form of a right tetrahedron as in Figure 1b because, in practice, calculations can be greatly simplified by using rectangular, rather than the conventional triangular, coordinates. For convenience in calculation the equilibrium surface is presented in one plane as a contour or parameter plot. Figure 1c represents the surface of Figure 1b (or Figure 1a) as a parameter plot on cartesian cobrdinates. In Figure 1c, x_C, the weight fraction of component C, is plotted vs. x_A, the weight fraction of component A. Compositions on the equilibrium surface are represented by lines of constant x_D, the weight fraction of component D. On such a plot, a single point can represent a liquid composition on the equilibrium surface. For example, point C_R^E on Figure 1c represents a liquid of composition $x_A = 0.300$, $x_C = 0.467$, and $x_D = 0.150$. The mole fraction of B, x_B, is obtained from the relation $x_A + x_B + x_C + x_D = 1$ and is 0.083.

Similarly, more complex systems lend themselves to this type of representation. Thus the equilibrium surface of a quaternary system which contains two partially miscible binaries is shown as a right tetrahedron in Figure 2a and as a parameter plot in Figure 2b. A system composed of three partially miscible binaries is shown in Figure 3.

Contour plots of equilibrium surfaces can best be prepared by cross-plotting experimental data. Since regularities appear in this type of representation, a minimum amount of quaternary data would be required.

TIE-LINE DATA

Few methods of presenting quaternary tie-line data have been suggested in the literature. The method of Brancker, Hunter and Nash (*2*) and that of J. C. Smith (*9*) are not suited to the convenient determination of tie

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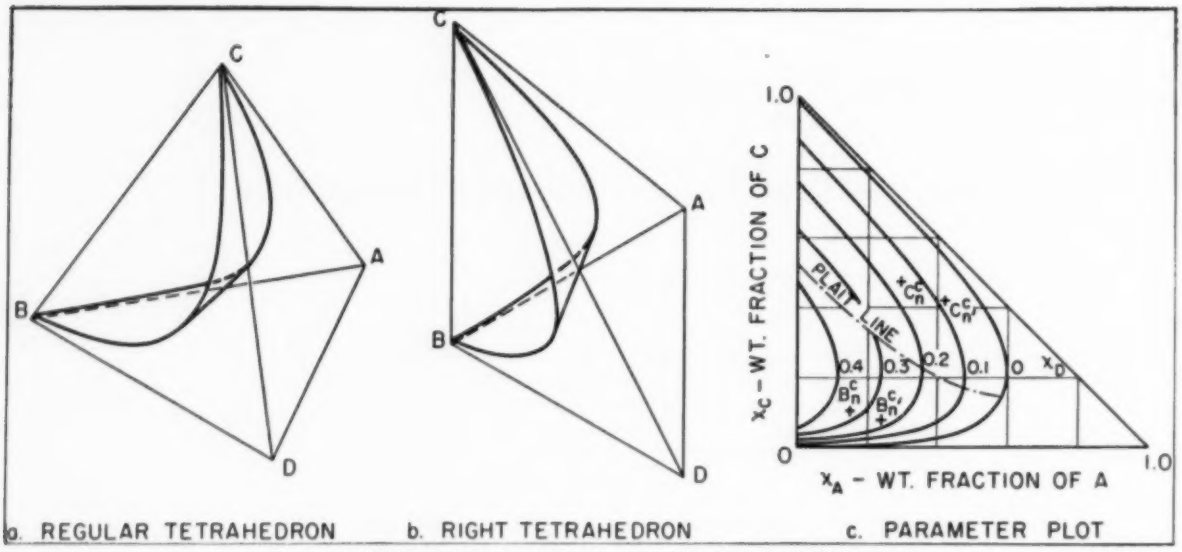


Fig. 1. Equilibrium surface of a quaternary system with one immiscible binary.

lines. For the design of cascade processes it is necessary to have a rapid method of determining the composition of the phase existing in equilibrium with a saturated liquid phase of known composition.

Tie-line data for any quaternary system existing as two phases can be conveniently presented by means of a pair of parameter distribution plots. Such representation is justified by Gibbs' phase rule which verifies that the complete compositions of two liquid phases in equilibrium at a given temperature and pressure are specified if the weight fractions of two components in either phase are designated.

Tie-line data for a typical quaternary with one partially miscible binary are presented in Figure 4. In order to differentiate between the two phases in equilibrium, the term $(x_A)_C$ is used to represent the weight fraction of component A in the C-rich phase and $(x_A)_B$ designates the weight fraction of component A in the B-rich phase. The weight fractions of the other three components are designated in an analogous manner by $(x_B)_B$, $(x_B)_C$, etc.

The equilibrium surface for this same quaternary was presented in Figure 1c and is used in conjunction with the tie-line data (Figure 4). For the quaternary under consideration, the two phases in equilibrium become identical at a series of compositions on the equilibrium surface. The locus of the points representing this series of compositions corresponds to the plait point in a ternary system and is designated as the *plait line*. Plait-line compositions appear on the 45° lines of Figures 4a and 4b and are cross-plotted on Figure 1c. All compositions on the equilibrium surface in Figure 1c which lie above the plait line exist in the C-rich phase, and all points below this line correspond to compositions existing in the B-rich phase.

As an illustration of the use of this type of tie-line representation, the composition of the liquid phase existing in equilibrium with the liquid represented by point $C_n{}^e$ in Figure 1c will be determined. On Figure 1c the liquid represented by point $C_n{}^e$ exists in the C-rich phase and therefore the composition is given as $(x_A)_{C_n} = 0.300$, $(x_B)_{C_n} = 0.083$, $(x_C)_{C_n} = 0.467$, and $(x_D)_{C_n} = 0.150$, where C_n refers to this specific C-rich liquid. The point $(x_A)_{C_n} = 0.300$, $(x_D)_{C_n} = 0.150$ is located on Figure 4a, and the value of $(x_A)_{B_n}$ is read on the ordinate to be 0.146. Similarly $(x_D)_{B_n}$ is found from Figure 4b to be 0.332. The two weight fractions $(x_A)_{B_n}$ and $(x_D)_{B_n}$ are plotted on the equilibrium surface (Figure 1c) as point $B_n{}^e$; and $(x_C)_{B_n}$ is found to be 0.091. Next $(x_B)_{B_n}$ is found by difference to be 0.431. Thus by the use of the two distribution plots, Figures 4a and 4b, in conjunction with the equilibrium surface plot (Figure 1c), it is found that the two liquid phases in equilibrium

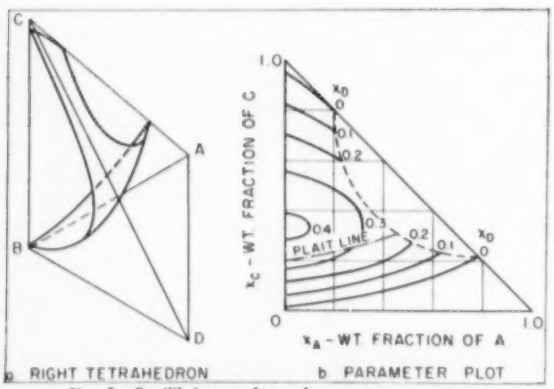


Fig. 2. Equilibrium surface of a quaternary system with two immiscible binaries.

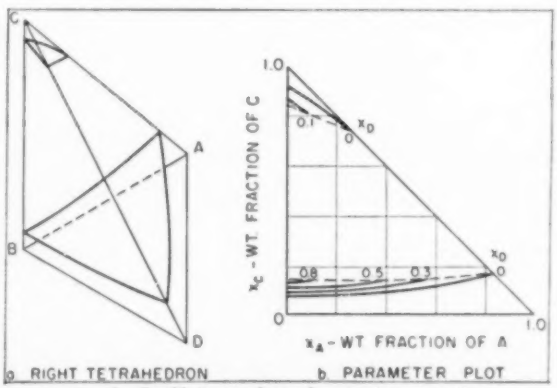


Fig. 3. Equilibrium surface of a quaternary system with three immiscible binaries.

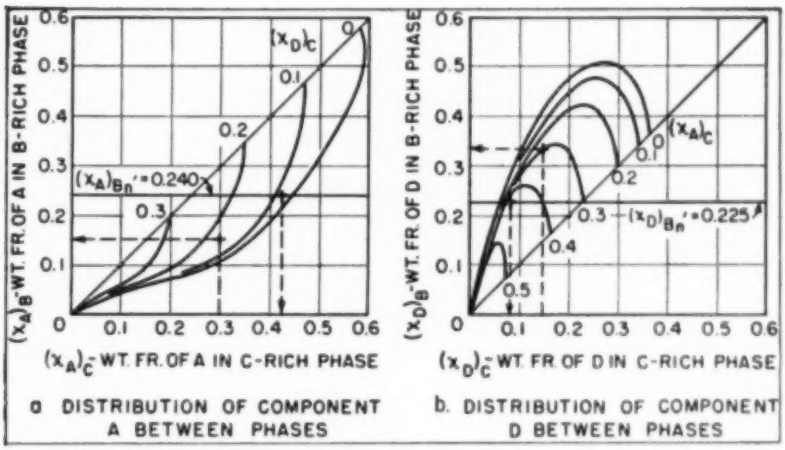


Fig. 4. Tie-line data for a quaternary system with one immiscible binary.

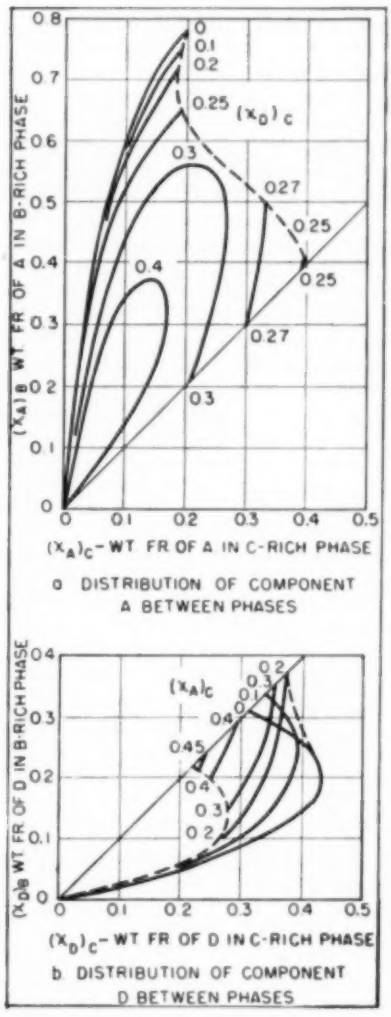


Fig. 5. Tie-line data for a quaternary system with two immiscible binaries.

have the compositions as shown in Table 1.

When Figures 4a and 4b are used to determine the composition of the C-rich phase in equilibrium with a specified B-rich phase, a simple trial-and-error procedure must be employed. Consider the saturated liquid of composition

$(x_A)_{B_{n'}} = 0.240$, $(x_B)_{B_{n'}} = 0.470$, $(x_C)_{B_{n'}} = 0.065$, and $(x_D)_{B_{n'}} = 0.225$

represented by point $B_{n'}$[c] on Figure 1c. The composition of $C_{n'}$, the phase in equilibrium with $B_{n'}$, is determined in the following manner: a horizontal line is drawn on Figure 4a, as the locus of all points representing $(x_A)_{B_{n'}} = 0.240$; and a similar line is drawn on Figure 4b to represent $(x_D)_{B_{n'}} = 0.225$. A value of $(x_A)_{C_{n'}}$ is assumed which determines values for $(x_D)_{C_{n'}}$ on both Figure 4a and Figure 4b. Successive values of $(x_A)_{C_{n'}}$ are assumed until the values of $(x_D)_{C_{n'}}$ obtained from both plots are identical. Several visual trials are sufficient to determine that $(x_A)_{C_{n'}} = 0.425$ and $(x_D)_{C_{n'}} = 0.075$. These values are plotted on Figure 1c as point $C_{n'}$[e] and $(x_C)_{C_{n'}}$ is found to be 0.418. The weight fraction of component B, $(x_B)_{C_{n'}}$ is calculated by difference to be 0.082.

This trial-and-error procedure is necessary because the tie-line data are represented in Figures 4a and 4b in terms of weight fractions in the C-rich phase as parameters. If sufficient calculations are to be made to warrant the extra labor, other tie-line-data plots can be prepared with weight fractions in the B-rich phase as parameters which will eliminate the trial-and-error procedure.

Tie-line data for more complex quaternary systems can also be presented as parameter plots. The tie-line data for a quaternary with two partially miscible binaries are presented in Figures 5a and 5b, and would be used in conjunction with Figure 2b. Similarly Figures 6a and 6b would be used with Figure 3b to represent the tie-line data for a quaternary system in which one component was partially miscible with the other three components.

Table 1.—Compositions

	C-rich Phase	B-rich Phase
x_A	0.300	0.146
x_B	0.083	0.431
x_C	0.467	0.091
x_D	0.150	0.332
	1.000	1.000

Actual Equilibrium Data

Figures 1 and 4 represent the system acetone (A)—water (B)—chloroform (C)—acetic acid (D)—at 25° C. They were prepared from equilibrium data on the two ternary systems acetone-water-chloroform and acetic acid-water-chloroform by the method suggested by Brancker, Hunter and Nash (*2*). Figures 1c, 4a and 4b agree satisfactorily with the quaternary equilibrium data provided by the same authors.

Figures 2, 3, 5, and 6 were also prepared from ternary equilibrium data, but are not meant to represent any specific quaternary systems. They serve only to illustrate that complex quaternary equilibrium relationships can be presented in the form of parameter plots.

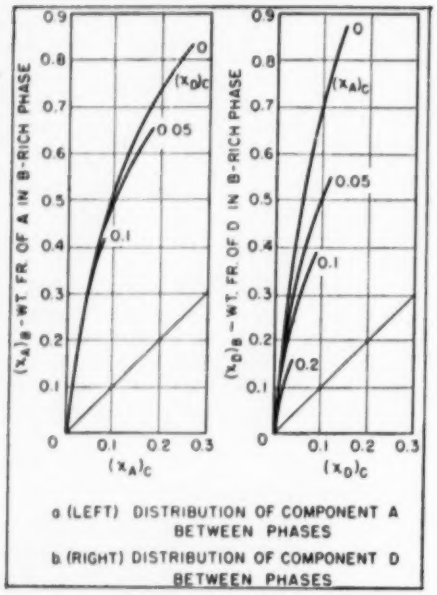
Graphical Techniques

Convenient presentation of equilibrium data is only a prerequisite for graphical calculations. The graphical procedures themselves are based on the fact that simple material balances can be made by drawing straight lines on a system of coordinates representing the compositions of material streams. Two simple examples will illustrate how the straight-line graphical material balance, which has been successfully used for ternary liquid-liquid extraction design, can be applied to quaternary systems as well.

MATERIAL BALANCE FOR TWO COMBINING STREAMS

Two material streams *J* and *K* mixing in steady state to form a third stream Σ, as represented by Figure 7*a* should be considered. The amount and composition of streams *J* and *K* are assumed to be known and the composition of stream Σ is to be determined graphically.

On Figure 8*a*, points J^c and K^c are plotted with coordinates $[(x_A)_J, (x_C)_J]$ and $[(x_A)_K, (x_C)_K]$, respectively. A straight line drawn between J^c and K^c must contain point Σ^c, with



a (LEFT) DISTRIBUTION OF COMPONENT A BETWEEN PHASES

b (RIGHT) DISTRIBUTION OF COMPONENT D BETWEEN PHASES

Fig. 6. Tie-line data for a quaternary system with three immiscible binaries.

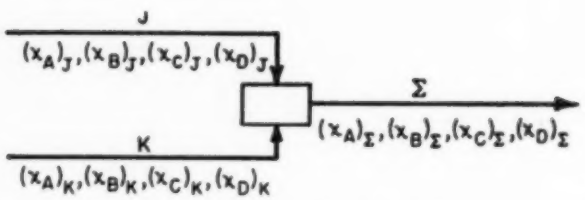


Fig. 7a. Two combining material streams.

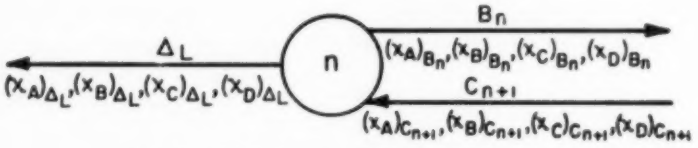


Fig. 7b. Net streams around equilibrium stage n.

Fig. 7. Flow diagrams.

coordinates $[(x_A)_\Sigma, (x_C)_\Sigma]$. Point Σ^a may be located graphically from the relation

$$\frac{\text{amount of stream } K}{\text{amount of stream } J} = \frac{\overline{J^a\Sigma^a}}{\overline{K^a\Sigma^a}}$$

where $\overline{J^a\Sigma^a}$ and $\overline{K^a\Sigma^a}$ are the linear distances from points J^a to Σ^a and from K^a to Σ^a, respectively.

With the location of point Σ^a, $(x_A)_\Sigma$ and $(x_C)_\Sigma$ are determined. For a ternary system $[(x_D)_J = (x_D)_K = 0$ in Figure 7a] the weight fraction of the third component $(x_B)_\Sigma$ can be calculated by difference.

The calculation procedure illustrated on Figure 8a is independent of the total number of components present in the system. To extend the method of quaternary systems, an analogous calculation is made with components C and D. Figure 8b illustrates such a calculation and the location of point Σ^b determines $(x_D)_\Sigma$. The weight fraction of the fourth component in the Σ stream $(x_B)_\Sigma$ is determined by difference.

MATERIAL BALANCES UTILIZING EQUILIBRIUM DATA

In the general case of graphical material balances encountered in the design of complex commercial processes, insufficient information is available to determine the composition of the unknown stream by the method illustrated in Figure 8.

For example, one can consider the equilibrium stage represented schematically in Figure 7b. The material balance around stage n involves three net streams and can be written as $B_n + \Delta_L = C_{n+1}$. B_n represents the B-rich stream leaving the nth stage, C_{n+1} is the C-rich stream entering stage n countercurrent to B_n and Δ_L is the net flow to the left. The compositions of streams B_n and Δ_L are assumed to be known and the composition of stream C_{n+1} is to be determined. The amount of stream B_n is unknown so that the method illustrated in Figure 8 cannot be applied. However, since C_{n+1} is assumed to be a saturated liquid stream, equilibrium data can be used to complete the material balance.

For ternary systems a line is sufficient to represent all isothermal saturated liquid compositions. The intersection of this line with the material-balance line determines the composition of stream C_{n+1}. Point $C_{n+1}{}^a$ is located in this manner on Figure 9a.

For quaternary systems the locus of all saturated liquid compositions is the equilibrium surface. In calculations involving four component systems, it is the intersection of the material-balance line with the equilibrium surface that determines the composition of stream C_{n+1}. The intersection is found by a simple trial-and-error procedure. This method is illustrated in Figures 9b and 9c. The material-balance lines are drawn from $\Delta_L{}^b$ to $B_n{}^b$ and from $\Delta_L{}^c$ to $B_n{}^c$. A value of $(x_C)_{C_{n+1}}$ is chosen for the first trial which determines $(x_A)_{C_{n+1}}$ in both Figures 9b and Figure 9c. Successive trials will locate the unique point on the material-balance line for which the values of $(x_A)_{C_{n+1}}$ are identical on both plots. Several visual trials are usually sufficient to locate the desired points, $C_{n+1}{}^b$ and $C_{n+1}{}^c$. The identity of $(x_D)_{C_{n+1}}$ on both plots can be used to check the solution. Alternately $(x_D)_{C_{n+1}}$ can be used for the original determination and $(x_A)_{C_{n+1}}$ will then serve as the check.

Extraction Process Design

The general approach to design problems is the same for ternary and quaternary systems: the desired separation specifications are prescribed, certain operating variables are set, and the required number of equilibrium stages is determined. Use of the calculation techniques described in the preceding sections will be illustrated by a design example. Consider the countercurrent, center-fed, fractional-extraction process represented in Figure 10. A feed solution F, composed of 50% acetone (A) and 50% acetic acid (D), is to be separated by extracting with pure water (B) as solvent S_B and pure chloroform (C) as solvent S_C. The cascade is assumed to operate isothermally at 25° C., the temperature level of the equilibrium data presented in Figures 1, 4, 11 and 14. It is desired to recover 90% of the acetone in the C-rich product stream C_1 and to maintain the weight ratio of acetone to acetic acid at 9.00 in this stream. Only two more operating conditions can be set independently, and, in order to make the initial over-all material balance, the two solvent rates must be specified. For this example, design S_B is set at 0.75 lb./lb. of feed and S_C is set at 1.00 lb./lb. of feed.

OVER-ALL MATERIAL BALANCE

The over-all material balance for the extraction process can be written

$$F + S_B + S_C = C_1 + B_1. \qquad (1)$$

where B_1 is the B-rich product stream. The amounts and compositions of all streams entering the process have been specified and the amounts and compositions of the two product streams are to be determined. The product streams leave equilibrium stages and are there-

fore saturated liquids. This fact, combined with the product specifications, permits the product stream compositions to be determined in the following manner: the entering streams are combined algebraically into one summation stream according to the defining equation

$$F + (S_B + S_C) = F + \Sigma_1 = \Sigma_2. \qquad (2)$$

On Figures 11a and 11b the points Σ_1^a and Σ_1^b are located on the lines joining S_B^a to S_C^a and S_B^b to S_C^b by the method illustrated in Figure 8. Σ_2^a and Σ_2^b are located in an analogous manner on the lines joining Σ_1^a to F^a and Σ_1^b to F^b. From the over-all material balance, Equation (1), $\Sigma_2 = C_1 + B_1'$, and therefore points Σ_2^a, C_1^a, and $B_1'^a$ lie on a straight line, as do points Σ_2^b, C_1^b, and $B_1'^b$. The compositions of streams C_1 and B_1' must be represented by points on the equilibrium surface and satisfy the initial product requirements. By suitable material balances the product specifications can be put into the form of equations: $(x_A)_{C_1}/(x_D)_{C_1} = 9.00$ and $(x_A)_{B_1'}/(x_D)_{B_1'} = 0.111$. The loci of points on the equilibrium surface which satisfy these equations are plotted as the dashed lines on Figures 11a and 11b. A trial-and-error procedure is followed until lines drawn through Σ_2^a and Σ_2^b intersect the dashed lines in such a manner that $C_1^a = C_1^b$ and $B_1'^a = B_1'^b$. The compositions of the two product streams are thus determined to be:

	C_1	B_1'
x_A	0.305	0.039
x_B	0.019	0.566
x_C	0.642	0.043
x_D	0.034	0.352
	1.000	1.000

The amounts of these streams can be determined by the known quantities of components A and D which are in the product streams.

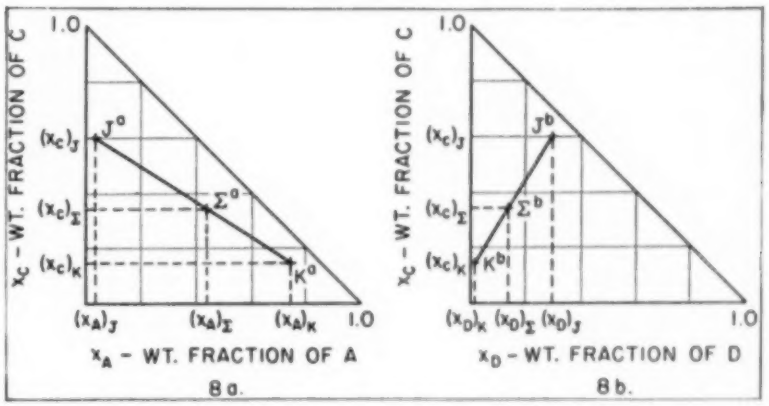


Fig. 8. Graphical material balance for two combining streams.

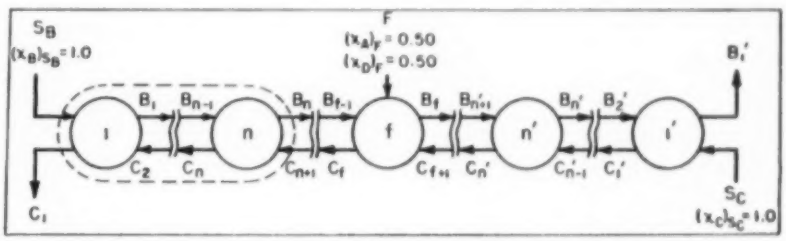


Fig. 10. Countercurrent center-feed fractional-extraction process without reflux.

Stagewise Calculations

To facilitate the stagewise calculations through the process, general material balances are made in the two sections of the cascade. Arbitrarily the section to the left of the feed stage in Figure 10 can be designated as the *enriching section* and that to the right the *stripping section*. For the enriching section a general material balance around the nth stage can be made which will include all material entering and leaving the system enclosed by the dashed line in Figure 10. This material balance is written

$$C_1 - S_B = C_{n+1} - B_n = \Delta_E = (F + S_C) - B_1' \qquad (3)$$

where Δ_E is the net material flowing from the feed stage through the enriching section. The equality on the right results from the over-all material balance. In order to locate the Δ_E^a and Δ_E^b points (the enriching section operating points) graphically, F and S_C are combined (by the method of Figure 8) into the Σ_3 stream on Figures 11a and 11b. Since $C_1 - S_B = \Delta_E = \Sigma_3 - B_1'$, Δ_E^a must lie on the line joining C_1^a to

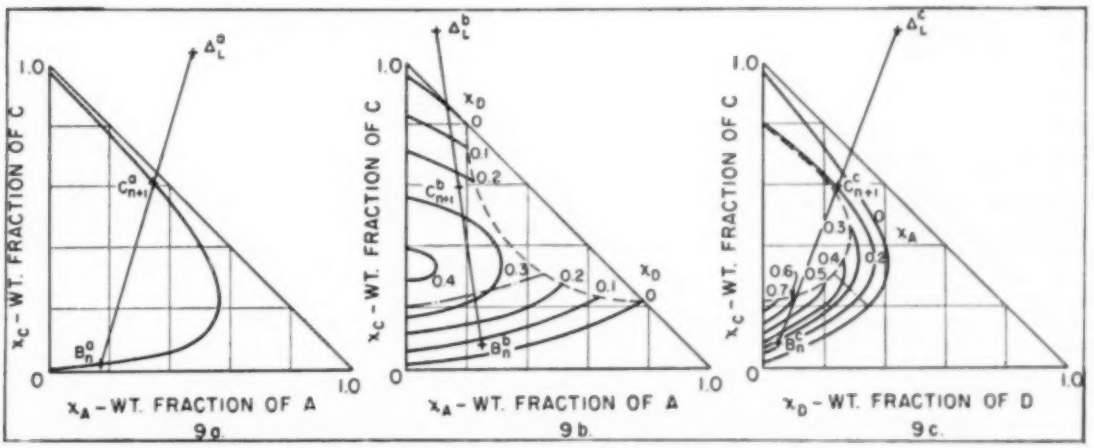


Fig. 9. Graphical material balances utilizing equilibrium data.

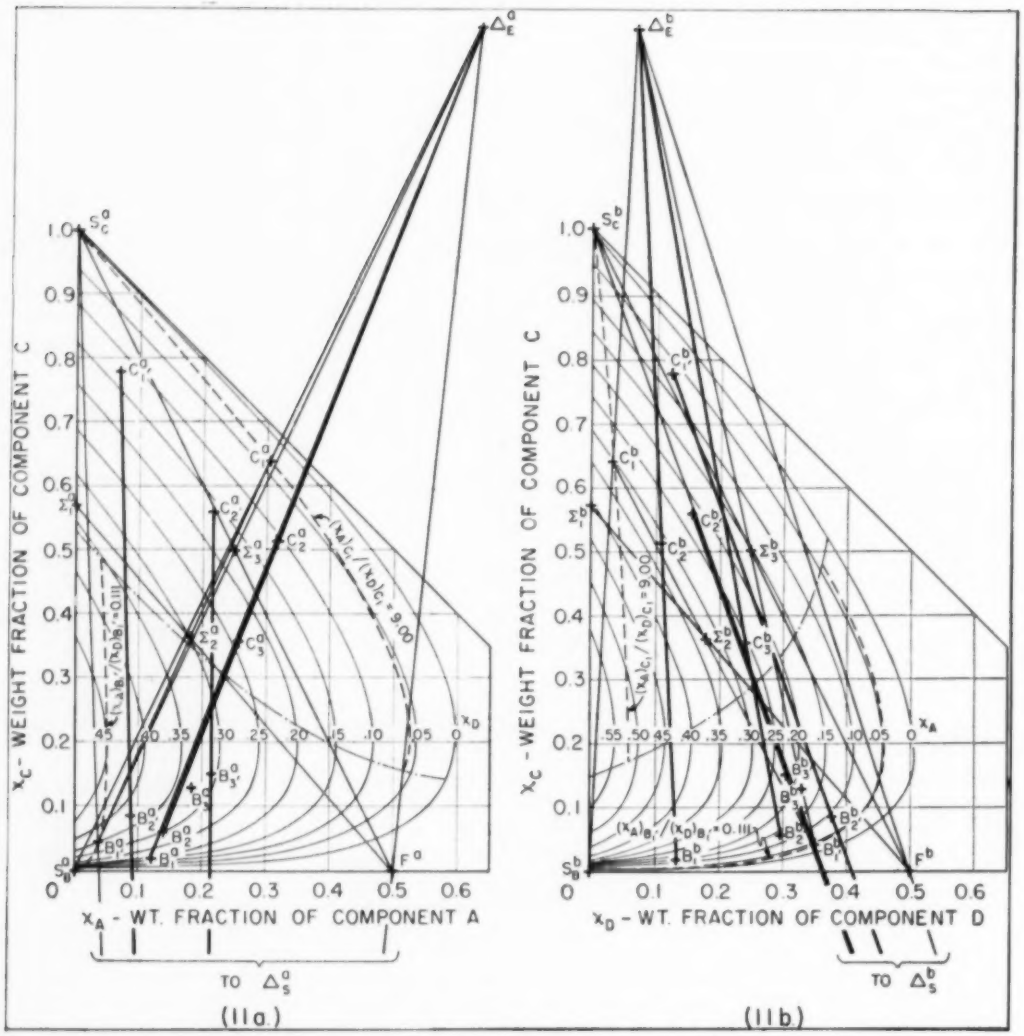


Fig. 11. Graphical design of countercurrent center-feed fractional-extraction cascade without reflux on equilibrium surface plots.

S_B^a and the line joining Σ_3^a to B_1^a. Point Δ_B^b is located on Figure 11*b* in an analogous manner.

The same general procedure is followed for the stripping section; Δ_B^a and Δ_B^b (the stripping section operating points) are located from the material balance equalities $B_1' - S_C = \Delta_B = F - \Delta_E$.

Stagewise calculations can now be made with ease. The calculation originating with the known composition of stream C_1 and made through the enriching section can be considered first. Since stream B_1 is assumed to be in equilibrium with stream C_1, the composition of stream B_1 is determined from the tie-line data, Figures 4a and 4b, and plotted on Figure 11a and 11b as B_1^a and B_1^b. It follows from Equation (3) that $\Delta_E = C_2 - B_1$ and therefore C_2^a lies on the line joining Δ_E^a to B_1^a and C_2^b lies on the line from Δ_E^b to B_1^b. Points C_2^a and C_2^b are located by the trial-and-error procedure illustrated in Figures 9b and 9c. This calculation procedure is repeated for several stages on Figure 11, and the results are summarized on Figure 12 where the weight fractions of the distributing components in the B-rich streams are plotted against the stage number.

A similar calculation is made (on Figure 11) starting with the known composition of stream B_1', and using the stripping section operating points Δ_B^a and Δ_B^b and the tie-line data of Figure 4. A simple trial-and-error procedure, as outlined in the section on representation of the tie-line data, is used with Figure 4 to obtain equilibrium compositions for the calculations through the stripping section. These calculations are also summarized on Figure 12. The feed stage is located by matching the compositions of the distributing components as suggested by Scheibel (*8*). There are 2.9 stages in the enriching section, including the feed stage, and 1.8 stages in the stripping section for a total of 4.7 stages.

Determination of Optimum Operating Conditions

The optimum operating conditions for any given set of product requirements are mainly a function of the cost of stages and cost of solvent recovery. By making a series of complete design calculations as described above at various solvent rates, a plot of the number of stages vs. solvent rate can be prepared. Since two solvent rates must be specified, a plot with the solvent ratio S_C/S_B as a parameter is used to show the effect of varying solvent rates on the number of stages required. Figure 13 illustrates this relation for the product specifications of the example problem. Such a plot can be used in conjunction with cost data to determine the optimum operating conditions.

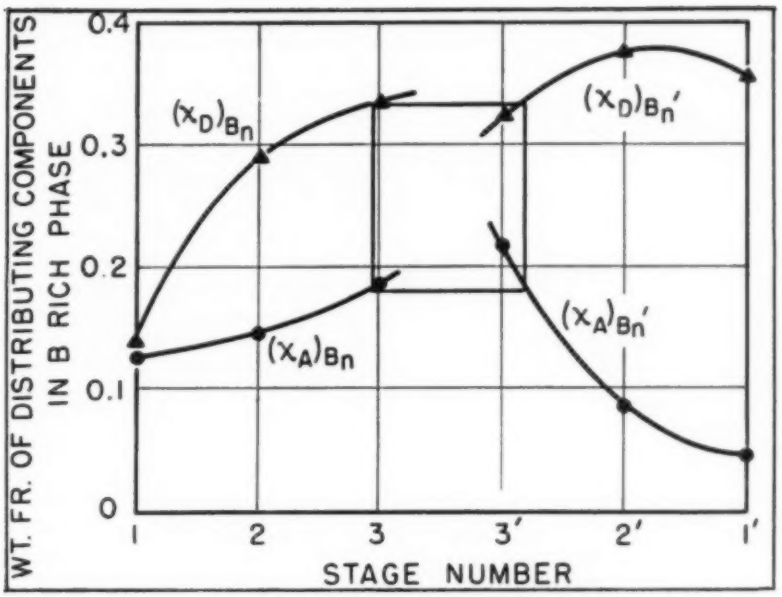


Fig. 12. Location of feed stage by matching of distributing components.

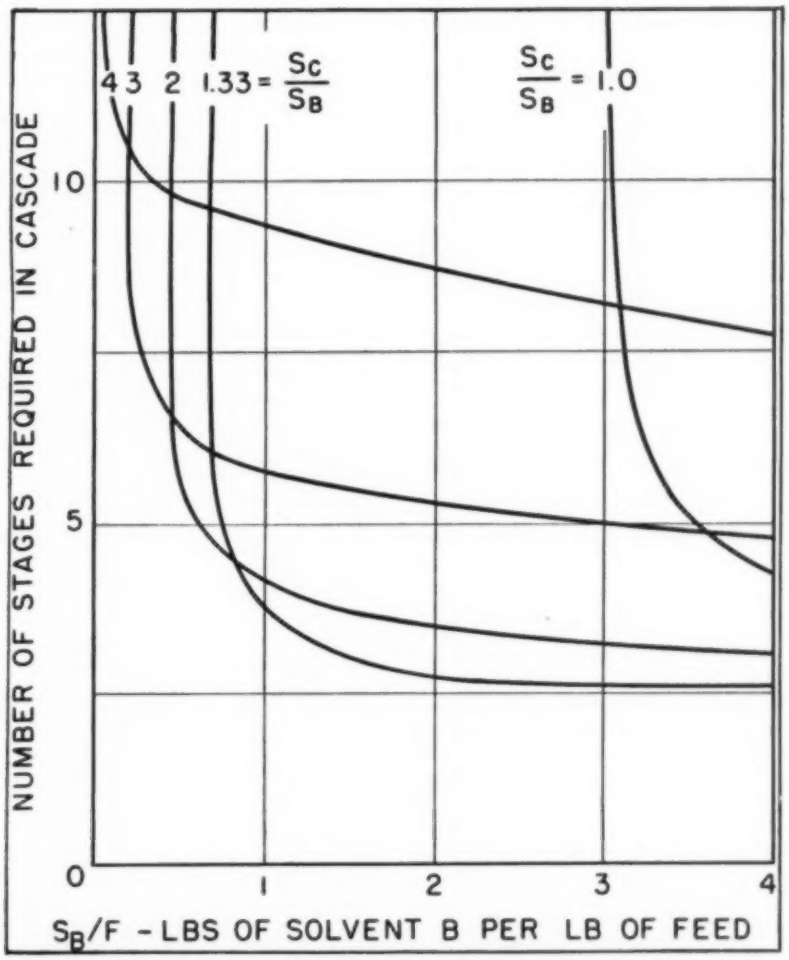


Fig. 13. Effect of varying solvent rates on number of stages required.

Other Applications

1. The graphical method proposed can be used to design most quaternary system extraction processes. Its application to batch extraction and to processes using mixed solvents is straightforward.
2. Although the details are not outlined here, the method can be used further for designs involving reflux, side streams, multiple feeds, or any of the various ramifications encountered in commercial practice.
3. By choosing suitable coordinate systems and parameters, this graphical method can be applied to equilibrium-stage calculations for any system of three independent variables such as complex liquid-solid extraction processes. If enthalpy is used as the third independent variable, the method can be applied to nonisothermal extraction processes and to ternary distillation processes in which combined enthalpy and material balances are required.

Acknowledgment

The suggestions given by Professor T. Vermeulen, Dr. E. J. Lynch, and Harriet Powers are herewith acknowledged.

Notation

A,B,C,D = components in a quaternary system. In the illustrative example, A = acetone, B = water, C = chloroform, and D = acetic acid

$B_1, B_2, \ldots$
$B_1, \ldots$
$B_n, \ldots$
$B_1, \ldots$ = B-rich stream leaving stage 1, 2, $\ldots n, \ldots n', \ldots$ 1'; also flow rate of this stream, lb./hr.

$C_1, C_2, \ldots$
$C_n, \ldots$
$C_{n'}, \ldots$
$C_1, \ldots$ = C-rich stream leaving stage 1, 2, $\ldots n, \ldots n', \ldots 1'$; also flow rate of this stream, lb./hr.

F = feed stream; also feed rate, lb./hr.

J, K = generalized stream; also flow rate of these streams, lb./hr.

$\overline{J^\circ\Sigma^\circ}$ = length of straight line on Figure 8a joining points J° and Σ°

$\overline{K^\circ\Sigma^\circ}$ = length of straight line on Figure 8a, joining points K° and Σ°

S_B = solvent stream, mainly component B; also flow rate of this stream, lb./hr.

S_C = solvent stream, mainly component C; also flow rate of this stream, lb./hr.

Δ_R = net stream flowing from feed stage through enriching section; also, flow rate of this stream, lb./hr.

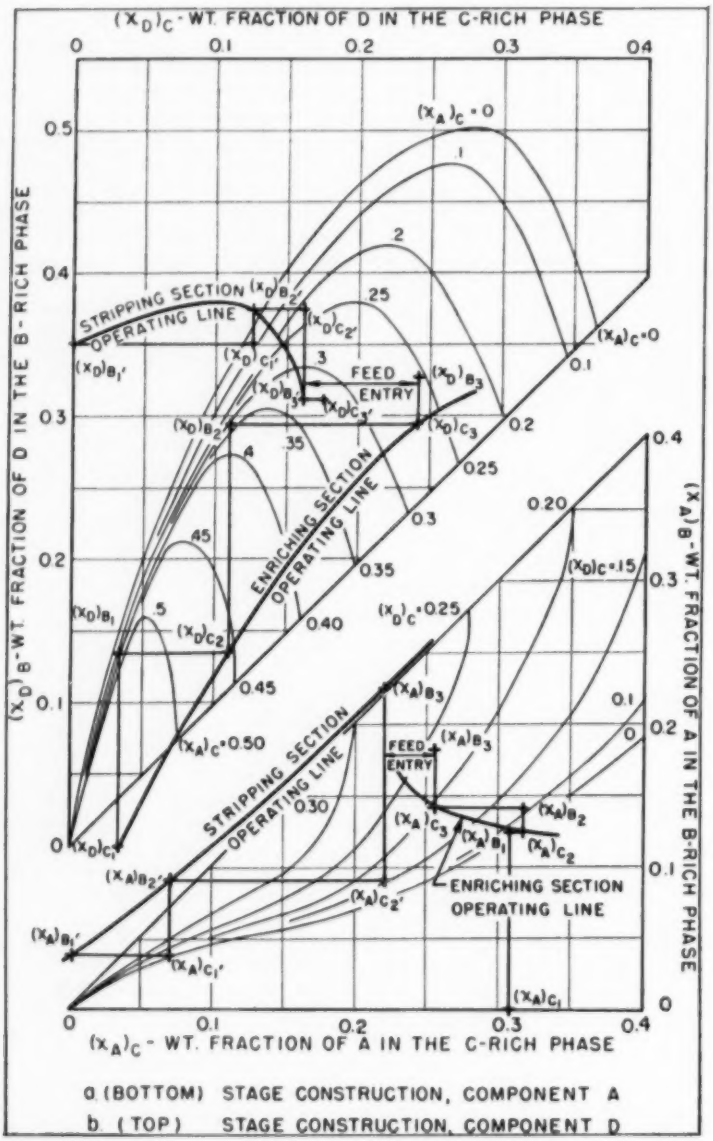


Fig. 14. Graphical design of countercurrent center-feed fractional-extraction cascade without reflux on parameter distribution plots.

Δ_L = general net stream flowing to left in Figure 7b; also, flow rate of this stream, lb./hr.

Δ_R = net stream flowing from feed stage through stripping section; also flow rate of this stream, lb./hr.

Σ, Σ_H

Σ_H, Σ_R = hypothetical summation stream; also flow rate of this stream, lb./hr.

f = feed stage

n = general equilibrium stage in enriching section

n' = general equilibrium stage in stripping section

x_A, x_B,

x_C, x_D = concentration, weight fraction of component A,B,C,D

1, 2, 3, . . . = equilibrium stage in enriching section, numbering toward the feed stage

1′, 2′, 3′ . . . = equilibrium stages in stripping section, numbering toward feed stage

SUBSCRIPTS

Capital Roman- and Greek-letter subscripts are added (outside of parentheses) to weight fractions to indicate the phase or stream to which the weight fraction applies. For example $(x_B)_C$ = weight fraction of component B in the C-rich phase and $(x_D)_{\Delta_R}$ = weight fraction of component D in net stream flowing through enriching section.

SUPERSCRIPTS

The superscript a, b, or c identifies a point on diagram a, b, or c of any particular figure, which has as its coordinates two weight fractions in the stream designated by the symbol to which the superscript is affixed. For example, C_n'' is the point with coordinates $[(x_A)_{C_n''}, (x_C)_{C_n''}]$ which appears on Figure 1c.

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Appendix

In order to be consistent and to limit the material covered in the body of this paper, the design method as described is almost entirely graphical. The compositions of streams Σ_2, Δ_R, and Δ_S can also be determined by analytical material balances, and compositions so calculated can be used to locate points Σ_2^a, Σ_2^b, Δ_R^a, Δ_R^b, Δ_S^a and Δ_S^b directly on the equilibrium-surface plots. When the analytical method can be applied (as in the case of the simple material balances), it is generally faster and more accurate than the graphical method.

The entire design procedure can be greatly simplified for certain calculations. When "operating lines" can be accurately estimated or calculated and the over-all material balance is known, the parameter distribution plots can be used in a manner analogous to the method described for ternary systems by Varteressian and Fenske (*11*). Figure 14 illustrates the application of such a method. The initial design specifications for this example are the same as those applied to the design illustrated in Figure 11. Chambers (*4*) has presented a similar calculation procedure for the design of extractive distillation processes.

Presented at A.I.Ch.E. San Francisco meeting.

Incremental digestion

Edwin A. Gee and Wilbert J. Huff

University of Maryland, College Park, Maryland, in cooperation with the Bureau of Mines, U. S. Department of the Interior.

By digesting silicate ores through incremental stages of acid treatment, their filtration rates have been increased tenfold—indicating possible wide application among certain marginal and submarginal ores of silicic composition.

As high-grade ore reserves are depleted, improved technology must utilize progressively lower grade raw materials to maintain the industrial strength of the United States. Better equipment, improved construction materials, and superior instrumentation are needed. Also important are potential fundamental advances in the scientific theories underlying the chemical and physical manifestations noted in the processing. In general, industry has avoided the use of silicates as source materials because of their general refractoriness to chemical decomposition, alkaline decomposition being handicapped by the loss of soda or caustic.

This investigation deals with the acid decomposition of silicates and specifically with the various factors influencing the separation of the silicic acid gel from the leach solution, an important barrier to the wider utilization of acid decomposition processes for silicates.

By changing the character of the gelatinous solid, an average tenfold increase in filtration rate over the rate in conventional practice was achieved. A hypothesis was proposed to explain the improved filtration characteristics obtained through incremental or stage digestion. This hypothesis was subjected to experimental attack and substantiated.

In olivine, an orthosilicate $(x\,Mg \cdot y\,Fe)_2SiO_4$, the mole fractions of Mg_2SiO_4 and Fe_2SiO_4 are respectively such that $x/y = 1$. Abundant and easily mined, olivine is an important potential source of magnesium, chromium, and nickel. It is mineralogically a member of the large group of orthosilicates which without exception exhibit gela-

Table 1.—Screen Analysis of Olivine

Particle size (mesh)	B
+20	0.0
−20 +48	19.8
−48 +65	30.1
−65 +100	17.1
−100 +200	9.4
−200 +325	14.1
−325	9.5

Edwin A. Gee is at present with Du Pont Co., Wilmington, Del.

Table 2.—Effect of Increment Variation

G. olivine added at			Filtration and washing rates		
0 min.	10 min.	20 min.	Series A	Series B	gal./(sq.ft.)(hr.) Difference
100	0	0	2.0	2.9	+0.9
60	20	20	6.5	5.8	−0.7
20	20	60	0.4	.5	+0.5
20	60	20	21.2	20.0	−1.2
30	60	10	15.2	14.6	−0.6
20	70	10	22.7	24.4	+1.7
15	75	10	15.2	12.2	−3.0
20	80	0	17.1	19.1	+2.0
25	75	0	18.1	19.3	+2.2
40	60	0	9.3	10.4	+1.1
50	50	0	5.4	6.8	+1.6

tion on decomposition, almost unfilterable slurries resulting under normal decomposition.

The olivine used in these experiments was obtained from Spruce Pine, North Carolina. It had the general formula $(Mg, Fe)_2SiO_4$, classified as an orthosilicate. Its chemical analysis showed

MgO	47.2%
SiO_2	42.5
FeO	7.5
NiO	0.35
Loss on ignition	2.3
	99.85%

Experiment

As a base line for research on modifying the structure of silicic acid gels resulting from the acid decomposition of silicates, numerous laboratory tests were conducted under varying conditions of time, temperature, and concentration. All initial studies were based upon the reaction of aqueous hydrochloric acid with olivine. It was found that the most favorable conditions were:

1. Acid concentration of 20% by weight.
2. Reaction temperature at the boiling point.
3. An over-all reaction time of 30 min.
4. An acid/ore ratio of 83-87% of theoretical.
5. Ore particle size approximately 100-mesh.
6. Neutralization of the excess acidity * prior to separation.

DEVELOPMENT OF INCREMENTAL DIGESTION

To produce a more dense silicic acid structure the olivine grind was divided in the laboratory into two portions, the first containing the bulk of the charge as relatively coarse material and the latter consisting of the fines. Eighty-five per cent of a charge corresponding to the screen analysis shown in Table 1 was reacted with the total stoichiometric quantity of 20% hydrochloric acid for 20 min.

The remaining 15% was added in a

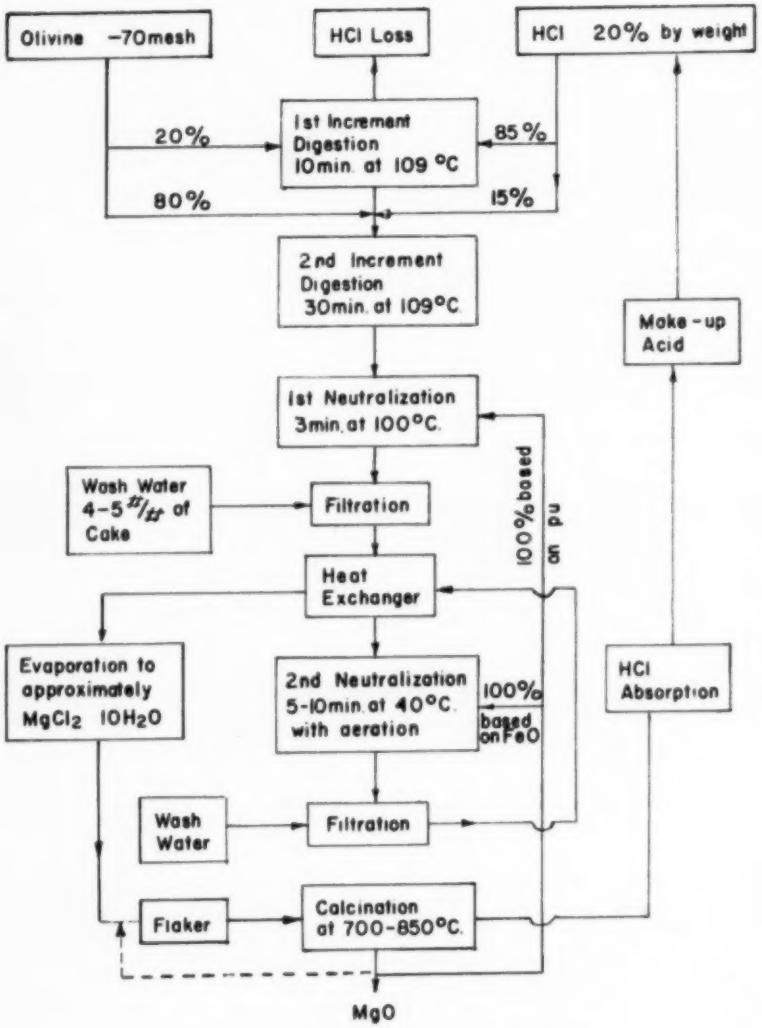

Fig. 1. Magnesia from olivine schematic flow sheet.

* Excess acidity =

$$\frac{\text{HCl} + \text{FeCl}_2 + \text{FeCl}_3 \text{ (in HCl equivalents)}}{\text{HCl} + \text{FeCl}_2 + \text{FeCl}_3 + \text{MgCl}_2 \text{ (in HCl equivalents)}} \times 100$$

Under these conditions laboratory tests on a Buchner funnel gave filtration rates of about 2 gal./(sq.ft.)(hr.).

Table 3.—Data on Complete Flow Sheet: Digestion, First Neutralization, and Filtration

	First neutralization Excess acidity Initial	Final	Utilization MgO, %	Filtration rate	$MgCl_2$, g./liter	FeO, g./liter	Wet cake, g.	Dry cake, g.	Wash-liquor retention, %	Filtrate, ml.
	10.2	1.1	76	9.4	230.7	1.2	186.1	65.0	65.0	355
	10.1	1.1	75	11.9	227.7	1.3	200.0	71.5	64.3	360
	10.6	1.3	84	12.2	227.7	1.5	195.0	69.7	64.3	370
	10.9	1.5	86	9.9	226.2	1.3	199.0	71.4	64.1	375
	11.4	1.5	90	11.1	216.8	1.7	193.0	69.8	63.9	377
	10.9	1.5	85	7.9	233.6	1.4	180.4	63.0	65.0	360
	11.2	2.1	83	7.6	236.8	1.4	178.3	57.0	67.9	345
	10.6	2.2	76	12.6	.....	..	175.6	67.0	61.8	365
	10.9	2.1	80	12.4	256.0	2.6	174.7	64.0	63.3	365
	10.4	...	..	11.6	234.6	1.6	181.8	64.0	64.7	385
Avg.	10.7	1.6	82	10.7	232.3	1.6	186.4	66.0	64.4	366

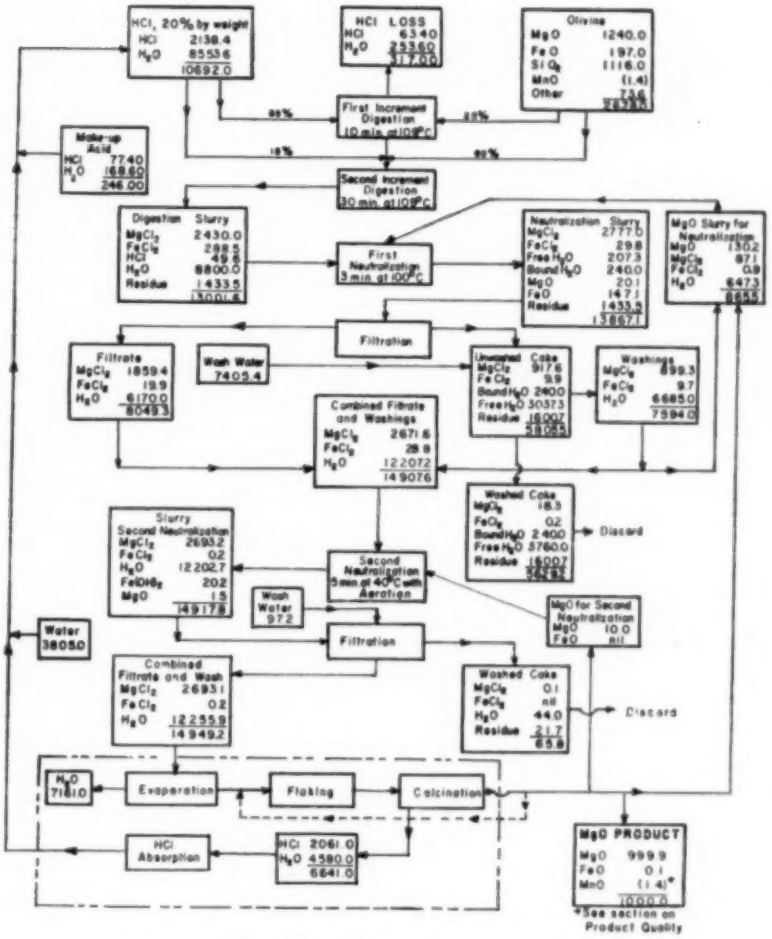

Fig. 2. Materials balance. Magnesia from olivine and hydrochloric acid.

smaller mesh size, that is, −100 or −200 mesh, and the final mixture digested for 10 min. to give the usual total digestion time of 30 min. A significant increase in filtration rate of the slurry occurred. As this was the first reported observation (*2*) of improvement due to such a technique, intensive small-scale tests were undertaken to determine its significance.

Because of the definite, if minor, improvement achieved with neutralization, the slurries from the 30-min. acid digestion were next neutralized with the theoretical requirement of magnesia, boiled for 15 min. additional, then filtered hot on a Buchner funnel. The particle sizes of all increments corresponded to those shown in Table 1. Results are shown in Table 2.

A marked difference existed in the physical characteristics of the residues obtained by incremental and nonincremental digestion. The product from the incremental digestion gave a relatively dry, granular structure, but nonincremental gave a gelatinous cake quite resistant to fluid flow.

DETERMINATION OF OPTIMUM CONDITIONS FOR INCREMENTAL DIGESTION—PILOT PLANT DESIGN

To utilize economically the potential decrease in operating and capital costs that might result from use of the incremental-digestion technique, optimum operating conditions for this technique were investigated.

In the laboratory a series of complete runs was made from the initial digestion to the final purification. The initial charge of 20 g. of olivine and 250 ml. of 20% acid was added to the reaction vessel cold, raised to boiling, and boiled for 10 min. The second increment containing 80 g. of olivine and 100 ml. of acid was then added as a cold slurry and boiled for an additional 30 min. Addition of cold slurry was practiced to avoid caking and excessive foaming when dry, finely divided olivine was added to the boiling reaction mixture. After digestion the slurry was neutralized with the theoretical quantity of magnesia as determined by the excess acidity at boiling for 3 min. and filtered hot. The cake was washed with 150 ml. of water which was combined with the filtrate. The combined filtrate and wash was neutralized with the theoretical quantity of magnesia and aerated at 40° C. for 10 min. before filtration. The

Table 4.—Data on Complete Flow Sheet: Second Neutralization and Purification

Second neutralization Excess acidity Initial	Final	Utilization MgO, %	$MgCl_2$ g./liter	FeO, g./liter	NiO, g./liter	SiO g./liter	MnO, g./liter	Wet cake, g.	Dry cake, g.	Filtrate, ml.
1.1	Alk.	92	241.1	< 0.001	< 0.001	0.008	0.13	3.2	1.7	322
1.1	Alk.	92	235.3	< 0.001	< 0.001	0.011	0.13	2.8	1.6	330
1.3	Alk.	93	230.7	0.003	< 0.001	0.044	0.14	3.0	1.1	345
1.5	Alk.	94	236.7	< 0.001	< 0.001	0.002	0.13	3.2	1.1	335
1.5	Alk.	94	224.2	< 0.001	< 0.001	0.012	0.13	2.9	1.2	350
1.5	Alk.	94	233.8	0.004	< 0.001	0.005	0.13	8.5	3.9	335
2.1	Alk.	95	230.6	0.003	< 0.001	0.002	0.10	8.2	3.8	330
2.2	Alk.	96	252.2	0.002	< 0.001	0.022	0.14	9.0	4.1	350
2.1	Alk.	95	256.8	0.003	< 0.001	0.029	0.16	11.1	5.0	360
...	Alk.	..	244.1	< 0.001	< 0.001	0.003	0.14	9.2	4.1	360
Avg. 1.6	Alk.	94	238.6	0.002	0.001	0.014	0.13	6.1	2.8	342

collected data, summarized in Tables 3 and 4, provide the basis for the flow sheet and material balance illustrated in Figures 1 and 2. Operations enclosed by broken lines are not deemed part of this paper and are based on analogous industrial operations.

THERMAL REQUIREMENTS

Simple thermal measurements gave an experimental heat of reaction (ΔH_{298}) of −49,300 cal. The reaction is highly exothermic and sufficient heat was liberated to maintain the slurry at boiling throughout the digestion period. The heat of reaction was also calculated from reported data (*1*) and was found to be −53,400 cal.

Pilot Plant Construction

The pilot unit allowed the batch reaction of 50-60 lb. of olivine with 20-25 gal. of acid. It is believed that this scale was adequate to demonstrate the industrial validity of the laboratory findings.

The unit consisted of ore hoppers, acid-storage tanks, acid-heating tanks, 68 gal. Haveg reactors equipped with Karbate reflux condensers and Haveg turbine-type agitators, a slurry mixing tank, Pyrex acid pumps, Hastelloy slurry pumps and Haveg piping. The filtration equipment consisted of a 3-ft. diam. 1-ft. face vacuum filter fabricated of Monel metal with a Monel screw as the filtering medium, a Sweetland-type pressure filter constructed of Monel with eleven leaves 8 in. in diam., and an 18-in. Bird centrifuge constructed of 304 stainless.

PILOT PLANT OPERATION

Acid was heated to 105° to 108° C. in the heater and pumped to the reactor. The first olivine increment was added through the charging nozzle and the agitator started. Five minutes after the maximum temperature was reached, the second increment slurry was pumped from the slurry tank into the reactor in about 5 min., as more rapid addition results in foaming out of the condenser vent.

The digestion slurry was reacted for the desired time, after which samples for excess acidity were obtained. From these, the desired MgO was computed, which was slurried with water or MgCl, solution and added to the digestion slurry.

The partially neutralized mass was then either centrifuged or filtered. The filtrate was analyzed for FeO, the amount of MgO needed for a given volume of liquor was calculated from this analysis, and the mass was reacted and aerated. This final slurry was filtered through the Sweetland filter, a filter aid being used to precoat the leaves. The final water-white liquor was sampled and analyzed.

The pilot plant digestions used 57 lb. olivine and 25 gal. HCl/batch. This was three hundred times the laboratory scale.

PARTICLE SIZE

Although the laboratory study had indicated the desirability of 100-mesh material, the first pilot plant digestions were run with 200-mesh olivine because of its availability. Although in the first increment no trouble was encountered, 200-mesh olivine was unsuitable for the second increment. When the second increment in the slurry was added too rapidly, reaction was so fast that the condenser flooded and material surged out of the vent. In attempting to reduce the rate of the second increment addition, it was found that in a short time the components reacted in the slurry tank to form a stiff paste that could not be pumped. Operating conditions were so critical as to indicate the use of such fine ore was impracticable. A new batch of the ore was ball milled to the screen analysis given in Table 5.

Table 5.—Screen Analysis of Olivine

Mesh size	Wt., %
−70 +100	10
−100 +200	50
−200 +300	25
−300	15
	100

TIME OF ADDITION OF SECOND INCREMENT

In the pilot plant it was found that the preferred time for the addition of the second increment was 5 min. after the first increment had attained its maximum temperature ±1° C. Usually this was 104 to 106° C. This procedure gave a filtration rate of 20 gal./(hr.)(sq.ft.) obtained by adding the second increment at a fixed time after the initiation of the reaction. Nonincremental digestion in the pilot plant gave a relatively unfilterable mass.

ACID-ORE RATIO

The first variable investigated was the ratio of acid to olivine. Runs were made in the range of 80 to 95.4% stoichiometrically required acid (on the basis of the MgO and FeO content of the olivine). Data confirmed laboratory findings that the actual MgO yield deviates from the theoretical by an increasing amount as the attempted per cent decomposition increases.

INCREMENT PROPORTIONS

Laboratory work had indicated the use of 20% of the olivine in the first increment and 80% in the second. Several incremental splits were checked in the pilot plant, the results again confirming the laboratory findings. The 10-90 split was inoperable as the first increment could not maintain the desired temperature, and the second increment had a considerable induction period before reacting; when it did react it could not be contained in the vessel, and a considerable loss through the vent resulted. Data from the pilot plant are given in Table 6.

A marked improvement in the filtration rate was obtained by lowering the first increment from 40 to 20%, the data being quite consistent. The 30-70 split with −200 mesh in the first increment showed plainly that the use of finely divided ore lowered the filtration rate. The higher filtration rates obtained with −70 mesh material in both increments with no substantial difference in yields or residual acidities, point to the use of this material.

REACTION RATE

The reaction rate in the pilot plant for 80% attempted decomposition was checked by residual acidity determinations, excess acidity values being essentially constant 30 min. after the second increment had been added to the reactor.

Evolution of Hypotheses for the Increased Filtration Rate Caused by Incremental Digestion

Consideration of gelation theory suggests three possible hypotheses for the phenomena of the increased filtration rate with incremental digestion:

1. Solution properties such as acidity, dissolved salts, or water content may be the principal factors,
2. Solid properties such as electrical charge, degree of hydration, or nucleation may be the principal factors,
3. The increased rate may result from a combination of steps 1 and 2.

The experimental results and evidence supplied by previous investigators show that high acid concentrations and/or small water-solid ratios are factors of considerable importance. These effects alone cannot account for the increased rate as the over-all acid concentration is identical with that for which prohibitively low rates are usually obtained.

In discussing the gaseous decomposition of olivine, Houston and Rankin (*3*) suggest that the formation of gelatinous silicic acid is avoided by the dehydrating action of magnesium chloride, which takes up water to form a series of hydrates and leaves the silicic acid in a granular condition. To test this hypothesis a series of digestions was performed in which 5, 10, 20, and 30

wt. % magnesium chloride was added to the raw acid. The only observable effect was excessive loss of raw acid because of its high vapor pressure.

Subsequent digestions were made with excess quantities of all of the various reactants and products added one at a time to the raw acid. No favorable improvement resulted. When the series was repeated using incremental digestion, the final filtration rate was substantially lowered.

The first hypothesis was further invalidated by following the usual incremental digestion technique except that after the first stage addition and usual reaction time, the resulting silicic acid was filtered off. The filtrate was identical in every respect with the environment into which the second increment of olivine was usually added except, of course, for the absence of the solid phase. The digestion of the second increment resulted in a prohibitively low rate of filtration, approximating 2 gal./(sq.ft.)(hr.) even though 20% less residual solid was present. Prior experimental data had, of course, indicated this conclusion.

That the effect was not due to a combination of solution and solid properties was shown by separating the silicic acid gel formed by the first increment, washing, and repulping with water until no chloride was shown with silver nitrate. The solid was then washed for two hours with 20% hydrochloric acid to replace as nearly as possible all absorbed and adsorbed water. This solid was subsequently added to a normal digestion of olivine and acid in which the total charge of ore was added directly to the acid. Filtration rates were five to tenfold those obtained by nonincremental digestion, the increased rate being a function of the residual solid or silicic acid.

The incremental digestion gave a silicic acid of less hydration, as indicated by contrasting microphotographs and by a comparison of the relative filtrate volume from incremental and normal digestions. The normal digestion gave only about 72% of the volume of filtrate given by incremental digestion. The filter cake from normal digestion was about double by volume that from incremental digestion. X-ray studies, however, show no difference in structure between the residue obtained by multistage and normal digestion.

To eliminate possible effects of the unreacted ore and the effects of gel conditioning by solution environment, a synthetic gel was produced by treating sodium silicate of reagent quality with a large excess of 20% hydrochloric acid to produce a gel free from iron, nickel, or similar ions present in olivine. The addition of this gel to a normal digestion of olivine gave filtration rates about five times those ordinarily obtained with normal digestion.

Large excesses of 20% hydrochloric acid cause prohibitively low filtration rates, weaker concentrations of hydrochloric acid cause gelation, but stronger concentrations of hydrochloric acid give increased filtration rates. The final reaction slurry obtained by any procedure must be neutralized to obtain the maximum increased rate.

Incremental digestion yields slurries that possess good filtration characteristics even at low temperatures, which is in direct contrast to slurries obtained by normal digestion.

Proposed Theory of Improved Filtration Rates with Incremental Digestion

The first increment of ore added to the strong acid reacts to form a gelatinous finely divided silicic acid gel which rapidly adsorbs hydrogen ions from the large excess of acid present; this agrees with the results of Losenbeck (*4*). Particles of the much larger second increment added to an over-all acid concentration which, under ordinary conditions would produce excessive gelation, are immediately coated with finely divided gel of the first increment. Adsorbed hydrogen ions on the surface of the initial gel are in preferred state for reaction, however, and their effective concentration is therefore much higher than indicated by the over-all acid concentration. Surface phenomena of this type, especially catalytic reactions, are not uncommon. The increased temperature at the phase boundary of gel and olivine minimizes hydration of the silicic acid colloid produced. The general conclusion is substantiated by the fact that higher concentrates of acid reacting at higher temperatures produce less highly hydrated residues.

The catalytic nature of the olivine-hydrochloric acid reaction was at least partially substantiated subsequently by an examination of the reaction kinetics and a general consideration of the controlling variables (*1*).

Silicic acid gel formed by this reaction is, then, in an ideal condition for aggregating and condensing with the gel of the first increment, which results in minimum entrainment and absorption of water. Aggregated silicic acid and free colloid present in the slurry after digestion, however, are in a highly charged condition, which prevents complete flocculation, and immediate filtration fails to achieve maximum rates. After neutralization the charge on the particles is removed, permitting the condensation of the colloid and giving a relatively coarse, quickly filtering, slightly hydrated residue.

EXTENSION OF THE THEORY

Tremendous tonnages of numerous silicates are available. Many have no commercial significance, and others do not react with 20% hydrochloric acid. Ten additional silicates that were free from or had possibilities of being freed from these objections were selected and studied. These are listed in Table 7.

As the theory established for the olivine-hydrochloric acid reaction required for its basic mechanism only silicic acid gel and hydrogen ions, it was felt that all gelatinizing silicates should be benefited by the technique of incremental addition. This view was supported by the results of tests using "synthetic" gel from reactions of sodium silicate and hydrochloric acid, as may be seen in Table 8. According to the data of Murata (*5* and *6*), it could be predicted therefore that olivine, serpentine, sodalite, and possibly wollastonite would have better filtering characteristics with stage addition than garnierite, kaolin, chlorite, chryostile, talc, and heulandite. It will be noted that all the gelatinizing silicates gave improved filtration with the incremental digestion and that one mineral, garnierite, listed by Murata as a nongelatinizing silicate, also showed improvement. It is possible that the improved rate for this mineral can be attributed to substantial amounts of olivine, shown to be present by petrographic analysis. High grade concentrates of such minerals are utilized without mineralogical separation.

ALTERNATE ACIDS

The phenomenon of improved filtration was subsequently extended to mineral acids other than hydrochloric. Nitric and sulfuric acids were evaluated as indicative of the group. Comparable extent of reaction could not be obtained between olivine and 20% concentrations of these acids, and it was necessary to utilize solutions equivalent in hydrogen ion concentrations to 40% hydrochloric. With higher concentrations of these acids, that is, about 50%, the phenomenon of increased rate from use of incremental digestion disappeared, probably because of the low liquid-solid ratio and the higher temperature of reaction. In Table 9 are given the data obtained for hydrogen ion concentrations equivalent to 40% hydrochloric. From Table 9 it is apparent that improved filtration rates can be obtained with incremental digestion of a variety of gelatinizing silicates if mineral acids other than hydrochloric are used. These conclusions greatly extend both the theoretical and engineering significance of the development.

Table 6.—Effect of Variation in Increment Ratio †

Run no.	Increment ratio	Recovery, % of original material in olivine MgO %	FeO %	Filtration %	Excess acidity, %
		First increment minus 200-mesh, second increment minus 70-mesh olivine			
172	30-70	83.5	80.8	5.5	10.0
176		85.2	85.1	7.0	11.2
Avg.		84.3	83.0	6.3	10.6
		Both increments minus 70-mesh olivine			
184	40-60	78.5	71.2	8.4	12.5
186		80.5	73.2	5.8	10.7
188		84.0	77.6	8.5	10.5
Avg.		81.0	74.0	7.6	11.2
177	30-70	83.5	81.7	12.1	12.5
178		82.0	79.1	12.9	11.4
179		86.8	84.7	12.2	10.9
Avg.		84.1	81.8	12.4	11.6
181	20-80	80.6	75.0	20.0	11.3
187		83.2	76.5	19.5	13.7
189		80.6	76.3	19.5	11.1
Avg.		81.5	75.9	19.6	12.0

† Attempted decomposition—85.2%.

Table 7.—Silicates Tested

SILICATES	POTENTIAL ECONOMIC IMPORTANCE
Olivine	Source of magnesium, chromium and nickel
Serpentine	Source of magnesium, chromium and nickel
Beryl	Source of beryllium
Kaolin	Source of alumina, ceramics
Garnierite (siliceous nickel)	Source of nickel and magnesium
Chlorite	.....
Sodalite	.....
Chryostile	Nonflammable electrical and heat insulation
Talc	High-temperature insulation, cosmetics, filler
Wollastonite	Filler, ceramic bodies, welding flux
Heulandite	.....

Table 8.—Effect of Incremental Digestion on Various Silicates

Mineral	Preparation	Average filtration rate, Digestion: Normal	Incremental
	Gelatinizing silicates		
Serpentine	Calcined at 650° C.	3.1	7.1
Beryl	Calcined at 1,500° C. followed by quick water quench	50% H_2SO_4 digestion no difference in rate—low water-solid ratio	
Sodalite	Not calcined	7.4	10.9
Wollastonite	Not calcined	5.8	10.9
	Nongelatinizing silicates		
Garnierite (Siliceous nickel)	Calcined at 600° C.	5.8	10.6
Kaolin	Failed to react appreciably with 20% HCl	10.1	8.2
Chlorite	Substantially complete reaction with 20% HCl	16.2	16.8
Chryostile	same	5.0	4.2
Talc	same	15.8	12.6
Heulandite	same	11.9	13.0

Table 9.—Effect of Mineral Acid on Filtration Rates

Hydrochloric acid		Nitric acid		Sulfuric acid	
Nonincrement	Increment	Nonincrement	Increment	Nonincrement	Increment
2.9	10.4	4.8	10.2	5.0	11.3
3.1	11.9	4.5	10.8	5.8	11.0
3.2	12.9	5.1	11.1	5.8	12.1
3.0	9.9	4.5	10.5	6.0	10.9
3.1	11.3	4.7	10.6	5.7	11.4

Economic Significance

An economic analysis at price levels existing in 1948 showed important savings in operating and plant investment costs when the digestion process utilizing incremental digestion was employed instead of normal digestion. Incremental digestion permits direct utilization of filtration equipment without dilution, and savings in heat represent over 13% of the total operating costs. For a plant capacity of 100 tons or more MgO/day, the savings in heat requirements amount to 16,000,000 B.t.u./ton of MgO/day, which at $0.38/1,000,000 B.t.u. represents a savings of about six dollars.

Similar savings in capital investment can also be effected. For plants producing over 100 tons of MgO/day and utilizing the incremental digestion process proposed the investment in 1948 would have been $50,000 to $60,000/ton. The additional evaporator capacity and the additional building required for a plant utilizing the normal single-stage digestion process would bring the overall plant cost to $65,000 to $75,000/ton of MgO/day, or an average increase of approximately 27%.

Acknowledgment

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The illustration on the first page of the article shows the largest siliceous ore-refining plant in North America at Climax, Colo. Courtesy Climax Molybdenum Co.

Natural-Circulation Evaporation

two-phase heat transfer

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Boiling heat-transfer coefficients for an electrically heated 1-in. tube vertical, natural-circulation evaporator were measured for water, *iso*propyl and *n*butyl alcohols, carbon tetrachloride, and 35 and 50 per cent potassium carbonate solutions. Recirculation rates were measured.

Data are well correlated by use of either an empirical Dittus-Boelter form of equation or one based on bubble Reynolds and Nusselt numbers.

Heat-transfer data for a vertical, natural-circulation evaporator with six fluids of widely differing properties have been correlated and analyzed in terms of current theories of boiling heat transfer. For analytical summaries of the recent literature the reader is referred to the work of Jacob (*4*), Rohsenow (*9*) and Larson (*5*).

Boiling at a heating surface can occur when the temperature of the surface exceeds the saturation temperature of the liquid. In this paper the term surface boiling is used to indicate the formation of vapor bubbles at the heating surface, independent of conditions of bulk liquid temperature and flow. So-called local boiling occurs at the surface if the mass liquid temperature is below the saturation temperature. The liquid then is said to be subcooled. For flows with large subcooling, the vapor bubbles, it is believed, live their lives at the heat-transfer surface, first increasing in size and then collapsing (*3*). At intermediate and low subcooling, detachment of the vapor bubbles becomes more pronounced and the condensation occurs in the bulk of the liquid (*7*). The occurrence of boiling at the heating surface in a body of fluid at its saturation temperature has been called pool or nucleate boiling. The data reported here represent a study of surface boiling for conditions of net vaporization and of induced convection.

Equipment and Measurements

Data were obtained on a single-tube vertical evaporator, the particular features of the apparatus including the use of electrical heating to produce the heat fluxes and the use of a unique flowmeter devised to measure the natural-circulation flow rate.

A diagram of the assembled apparatus is given in Figure 1.

The component parts included an electrically heated vertical test section, a vapor head and separator, a condenser in which the fraction vaporized was continuously condensed and removed, and a constant head feed tank with a preheater which continuously provided make-up liquid feed. The vertical tube test section consisted of a 4-ft. 10-in. length of 1-in. nominal copper tubing, 1.068-in. I.D. and 1.313-in. O.D., surrounded by three sections of spirally wound heating coils. The heated length was 46.5 in. The heater coils were made from 3/16 in. × 0.032 in. Nichrome V ribbon, and were wound on insulating mica strips. 0.020 in. thick, which separated the coils from the varnished tube. Each coil had the same electrical resistance, and the three coils were connected in parallel. The entire assembly was insulated, and it was believed that a uniform heat flux to the tube was provided. Heat fluxes ranging from 1,867 to 52,500 B.t.u./(hr.)(sq.ft.) were supplied by 60 cycle a.-c. The net heat transferred to the fluid was calculated by summing the heat required to bring the feed solution to the boiling point, the latent heat as calculated from the weight of the condensate, and the calibrated heat losses from the evaporator sections other than the test section. For each run this summation was compared to the measured electrical heat input, and the difference used to indicate the heat losses, which averaged less than 2.5%, from the test section.

The liquid recirculation rate was measured by a special flowmeter consisting of a perforated, truncated, conical impact ring suspended by a spring and mounted in a glass tube through which the recirculating liquid flowed. An optical sighting arrangement was used to measure the deflections of the spring. At low rates of flow the impact ring was motionless, and at high rates a slight vertical oscillation was observed.

It has been shown that the above-described type of flowmeter is independent of wide variations in density and viscosity as long as the flow is turbulent (1, 12). The pressure drop through the flowmeter was not large enough to affect the flow rate. A calibration of the weight flow rate vs. deflection is a straight line on a log plot. The ranges of flow and heat flux are shown in Figure 2.

Calibrated copper-constantan thermocouples were used to measure tube-wall temperatures at locations noted in Figure 1. The thermocouple junctions were placed in 3/64 in. × 3/64 in. × 1/2 in. slots milled longitudinally into the outer tube wall, and the junctions were soldered to the tube at the end of the slots. The inside tube-wall temperature was obtained by subtracting the calculated temperature drop across the remaining wall thickness. Even for the highest heat fluxes, this correction was only about 0.7° C. Additional temperatures measured included fluid temperatures at the inlet and outlet ends of the test section, and the temperature of the make-up feed. The inlet fluid to the test section was within 1° C. of its normal boiling point.

Typical variations of the measured tube-wall temperatures are given in Figure 3, indicating values for water, *iso*propyl, and *n*butyl alcohol for high (*h*), intermediate (*i*) and low (*l*) heat fluxes. The low values for the inlet position T_7, particularly for the low and intermediate fluxes indicate unusually high heat-transfer coefficients near the entrance and/or a distortion of the heat-flux input. The nature of these deviations has not been resolved, and correlations presented are based upon the use of an arithmetically averaged wall temperature.

The six fluids tested were water, CCl_4, *n*butyl alcohol, *iso*propyl alcohol, 35 wt. % K_2CO_3 aqueous solution and a 50 wt. % K_2CO_3 aqueous solution. All runs were made at atmospheric pressure.

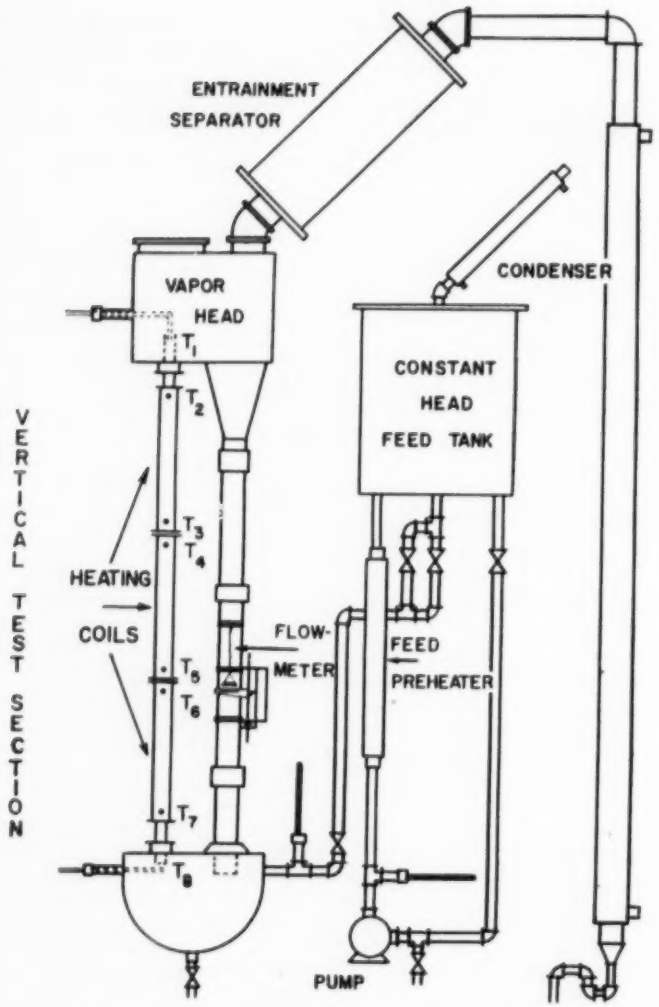

Fig. 1. Diagram of vertical-tube natural-circulation evaporator.

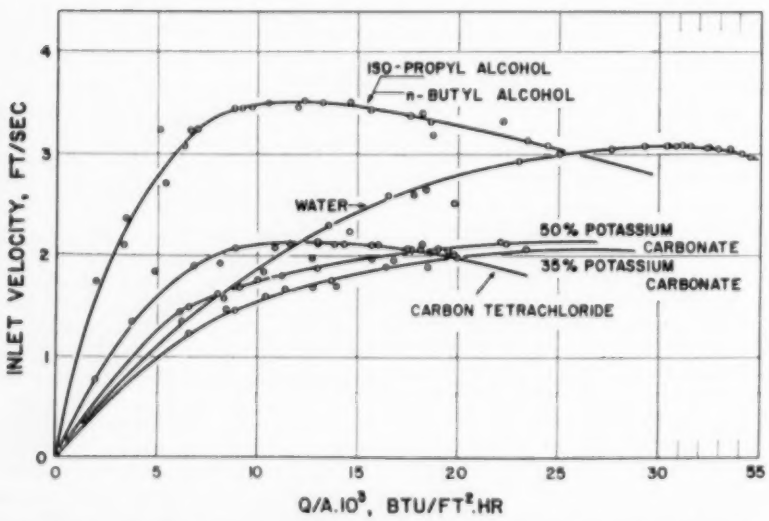

Fig. 2. Recirculation flow rates vs. heat flux. Inlet liquid velocities are plotted vs. heat flux for six fluids tested in vertical-tube natural-circulation evaporator.

Physical properties of the fluids at their normal boiling points (760 mm. Hg) are tabulated in Table 1.

In order to obtain consistent results, the test section was cleaned prior to each series of runs with a cloth swab wetted with a dilute solution of hydrochloric acid, washed with water, and rinsed with distilled water. For the nonaqueous runs, the test section was rinsed with ethyl alcohol and then by the specific solution. Fresh distilled water was used in each series of water runs, and the organic liquids were frequently distilled in order to ensure their purity. The potassium carbonate solutions were filtered and concentrations were adjusted frequently. Most runs were from 30 min. to an hour in length and duplicate measurements were taken of the wattmeter reading and current transformer ratio, feed temperature, six tube-wall temperatures, inlet and outlet fluid temperatures, and flowmeter reading. The condensate was collected for each run and weighed.

Representative data including a few calculated groups are given in Table 2, and Table 3 summarizes the range of variables covered. The data are presented in Figure 4 for plots of total heat flux, Q/A, vs. the mean-temperature drop across the liquid film, T_x.

Analysis

Current developments in surface-boiling heat transfer have established that the bulk of the heat transferred to the fluid flows through the liquid film on the heat-transfer surface and only a small fraction flows directly into the vapor bubbles (*10*). The bubble disturbances of the liquid film can become sufficiently violent at high heat fluxes to dominate the effective turbulence of the fluid (3). This accounts for the observation that at high heat fluxes surface-boiling heat-transfer coefficients become independent of bulk liquid velocity (*7, 9*). However, it should be noted that in one recent study this trend was not observed (*11*).

Rohsenow (*9*) has developed a correlation for pool boiling, which he extended to surface-boiling regimes with forced convection. The basic features of the correlation are the relations

Bubble diameter,

$$D_b = C_d\beta\sqrt{\frac{2g_c\sigma}{g(\rho_l - \rho_v)}}$$

Bubble frequency,

$$f = \frac{\text{constant}}{D_b}$$

Total heat-transfer rate Q/A is proportional to the number of streams or columns of bubbles.

Table 1.—Physical Properties of Liquids

NORMAL BOILING POINTS

Liquid	b.p.	h_{fg}	c_l	μ_l	k_l	σ	ρ_l	ρ_g	Pr
Water	212.0	970.2	1.000	0.687	0.393	58.9	59.83	0.0372	1.75
Carbon tetrachloride	170.1	83.5	0.209	1.17	0.056	20.4	92.5	0.34	4.36
n-Butyl alcohol	242.6	254.0	0.834	1.03	0.094	16.3	42.0	0.151	9.15
iso-Propyl alcohol	180.5	286.5	0.874	1.20	0.089	16.9	45.5	0.135	11.8
Potassium carbonate 35%	222.8	975.7	0.685	1.99	0.358	72.7	81.46	0.0367	3.81
Potassium carbonate 50%	237.2	982.9	0.609	3.51	0.344	89.0	92.63	0.0359	6.21

Data, except σ, h_{fg}, and μ for the potassium carbonate solutions, were obtained from values given in the literature (8). Surface tension and viscosity data were experimentally determined by Reveal (8) for the carbonate solutions; values for h_{fg} were estimated by using the steam tables, neglecting heat of solution effects.

Table 2.

SUMMARY OF DATA

(Representative values only)

No. Run	Q/A B.t.u./(hr.)(sq.ft.)	T_l	T_s ° F.	T_x	v_l	u_s ft./sec.	u_m	h_{av}	$\bar{h}$ Calc'd Eq. (4) B.t.u./(hr.)(sq.ft.)(° F.)
				24 Water Runs					
10	6140	212.7	210.4	10.01	1.35	7.80	3.67	612	546
1	13020	211.3	209.8	12.33	2.15	17.40	7.35	1054	952
24	33760	210.7	209.5	19.53	3.10	44.30	15.50	1728	1720
17	52500	210.0	208.9	24.60	3.00	68.00	20.80	2135	2175
				12 Isopropyl Alcohol Runs					
1	3421	179.2	178.2	13.87	2.37	5.27	3.62	247	297
6	10510	177.3	176.5	20.09	3.51	15.00	7.90	524	556
12	18680	177.3	176.5	27.55	3.19	24.10	10.40	679	691
11	27600	177.3	175.7	33.41	3.07	32.30	12.40	826	798
				14 n-Butyl Alcohol Runs					
1	5374	241.3	240.3	14.27	2.71	6.73	4.46	377	372
3	9677	242.2	240.7	16.76	3.47	12.40	7.09	576	539
9	15610	240.1	240.2	21.46	3.45	19.90	9.45	726	679
14	22180	242.2	240.2	26.88	3.34	25.90	11.10	825	771
				15 Carbon Tetrachloride Runs					
1	1867	170.1	166.5	17.09	0.77	2.39	1.42	110	82
4	8147	167.4	166.5	35.64	1.92	13.80	6.02	229	259
12	13050	165.4	164.1	40.70	2.09	21.50	8.33	320	336
15	17520	165.6	163.8	47.68	2.09	28.40	10.10	367	392
				14-35% Potassium Carbonate Runs					
14	6460	223.5	221.7	14.92	1.23	7.89	3.58	434	392
6	10390	223.5	221.9	18.27	1.58	13.10	5.46	569	551
1	16840	220.6	219.2	22.23	1.95	21.40	8.12	757	756
10	19890	221.4	220.3	24.34	1.99	25.40	9.19	817	835
				15-50% Potassium Carbonate Runs					
15	6081	241.2	238.8	15.03	1.44	7.70	3.75	396	346
10	9113	240.7	238.3	19.39	1.68	11.80	5.22	471	451
1	18960	234.4	233.1	25.67	2.08	24.90	9.25	738	712
2	22100	234.7	233.2	29.12	2.15	28.90	10.30	759	774

A bubble Nusselt number is defined as $Nu_b = hD_b/k_l$, where h is the surface-boiling heat-transfer coefficient, D_b is the bubble diameter, and k_l is the thermal conductivity of the liquid. The bubble Reynolds number is defined as

$$Re_b = \frac{D_b G_b}{\mu_l},$$

where G_b is the mass velocity of the bubbles leaving the heat-transfer surface and is equal to $(Q/A)/C_{sf}h_{fg}$, μ_l is the viscosity of the liquid, h_{fg} is the latent heat of vaporization, and C_{sf} is an empirical constant. Rohsenow reasoned that the significant relations for nonboiling heat transfer could well carry over into the boiling regimes. He obtained the following correlation for pool-boiling data using the bubble Nusselt and Reynolds numbers, and the Prandtl number for the liquid

$$Nu_b = \frac{1}{C_{sf}} Re_b^{2/3} Pr^{-0.7} \qquad (1)$$

This correlation transforms into

$$\frac{c_l T_x}{h_{fg}} = C_{sf}\left[\frac{(Q/A)}{\mu_l h_{fg}}\sqrt{\frac{g_c\sigma}{g(\rho_l-\rho_v)}}\right]^{0.33} Pr^{1.7} \qquad (2)$$

T_x is the heating surface temperature minus the fluid saturation temperature, and σ is the surface tension of the liquid. The value of C_{sf} depends both on the metal and on the liquid. Equation (2) has been applied here for both the total heat fluxes (Q/A), and the calculated pool-boiling fluxes $(Q/A)_b$.

Another approach toward correlating the data on surface boiling with net vaporization and induced convection has been used (8). In a model, perhaps oversimplified, it is assumed that the effective liquid-film thickness on the heat-transfer surface is inversely proportional to liquid-vapor mixture velocity which increases along the length of the tube so that a cumulative effect results.

The local surface-boiling heat-transfer coefficient is taken as $h_l = au^n$, where n could be expected to be near 0.8 and u is the local two-phase mixture velocity. The average surface-boiling heat-transfer coefficient h_{av} for the evaporator can be expressed then in terms of a velocity function integrated along the length of the tube. It was found by calculation for the conditions of the tests involving small weight fractions vaporized that the integrated velocity function is approximated to within 5% by $u_m^{0.8}$, where u_m is the log mean velocity over the inlet and exit sections of the evaporator. Linden and Montillon (6) first successfully introduced the log mean velocity type of correlation in their study of liquid film heat-transfer coefficients in an inclined tube, natural-circulation evaporator.

To extend the correlation, it was assumed that

$$Nu = \phi(Re_m, Pr) \qquad (3)$$

where the Nusselt number is taken as $(h_{av}D/k_l)$, the Reynolds number as $\left(Du_m/\frac{\mu_l}{\rho_l}\right)$, and Prandtl number is taken for the liquid $(c_l\mu_l/k_l)$. Inasmuch as the basis for this model involves bulk fluid velocities, the characteristic length for the flow inside the pipe is the pipe diameter D. The Reynolds number in single-

phase flow is representative of the ratio of turbulent to viscous forces. Although the relations are not this simple for two-phase flow, the approximation was made that the liquid film would determine the viscous drag and could be represented by μ_1/ρ_1; whereas the bulk flow would determine the turbulent forces and could be represented by Du_m. The modulus thus compounded along the length of the tube is

$$Du_m/\frac{\mu_1}{\rho_1}.$$

With the Nusselt and Prandtl numbers physical properties of liquid rather than vapor were taken since the bulk of the heat is transferred through a liquid film. The evaluation of the functional relationships in Equation (3) is presented in the next section.

Correlations and Discussion

Several methods of correlation can be applied for the six fluids used in the vertical tube natural-circulation evaporator. Though these correlations may not be general, they help in clarifying current developments in two-phase heat transfer.

All runs were made at atmospheric pressure. Thus, though the six fluids in themselves provided wide ranges in physical properties, the fluid properties were constant for the series of tests with any one fluid. In this work uniform electrical heat input was provided. the liquid entered the short tube test section at nearly its normal boiling point, and the weight fraction vaporized never exceeded about 5%. These tests were originally intended to provide local heat-transfer coefficients for surface boiling. As noted previously in the discussion of Figure 2, it was later decided to use an averaged wall temperature. All correlations presented involve the use of the averaged temperature difference T_w, defined as the difference between the average inside wall temperature and the normal boiling point of the fluid.

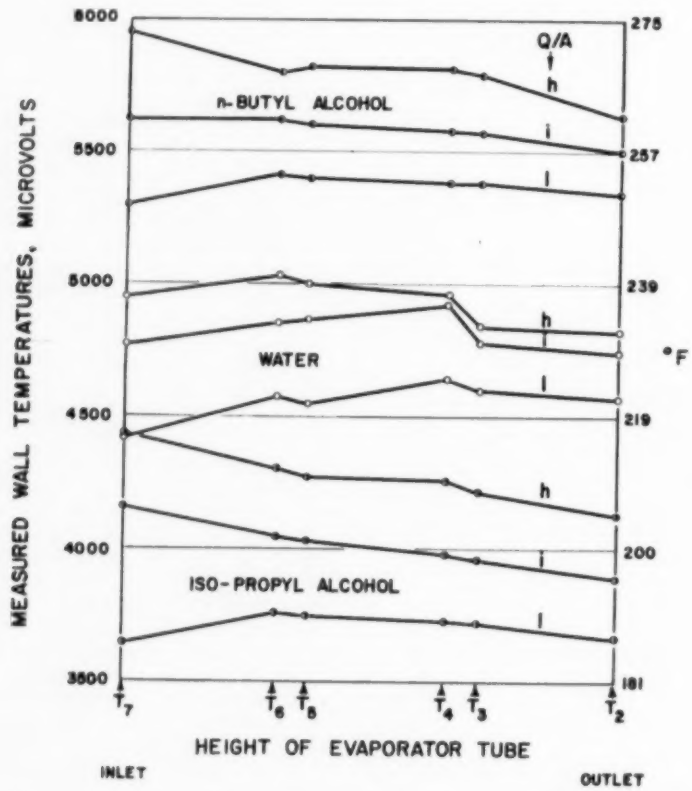

Fig. 3. Measured wall temperature profiles. Outside wall temperatures are plotted vs. heated length of the evaporator tube with T_7 1¼ in. from the entrance of heated section, and T_2 1¼ in. from the outlet. Typical runs are given for high (h), intermediate (i) and low (l) heat fluxes. The liquid temperature variation for each run was generally less than 1° C. from inlet to outlet.

Table 3.—Range of Variables

Variable	Max.	Min.	Range
c_1 B.t.u./(lb.)(° F.)	1.000	0.209	4.78
μ_1 lb./(ft.)(hr.)	3.51	0.687	5.11
k_1 B.t.u.(ft.)/(hr.)(sq.ft.)(° F.)	0.393	0.056	7.02
σ dynes/cm.	89.0	16.3	5.46
ρ_1 lb./cu.ft.	92.63	45.5	2.04
Pr_1	11.8	1.75	6.74
Nu	826.	102.	8.10
$Re_m \times 10^{-4}$	58.9	2.70	21.8
u_1 Inlet liquid vel. ft./sec.	3.54	0.77	.....
u_2 Outlet liquid-vapor vel., ft./sec.	68.5	7.8	.....

LOG MEAN CORRELATION

It was found that all the data (a total of 94 runs) with the six fluids could be fitted by the single relation

$$\frac{h_{av}D}{k_1} = 0.0086\left(\frac{Du_m\rho_1}{\mu_1}\right)^{0.8}\left(\frac{c_1\mu_1}{k_1}\right)^{0.6}\left(\frac{\sigma_w}{\sigma}\right)^{0.33} \quad (4)$$

The data, plotted in Figure 5, show a mean deviation of only 4%, with 91.3% of the runs having a deviation of less than 10%. The surface-tension ratio referred to that of water σ_w/σ was arbitrarily introduced and was successful in bringing the correlations for each fluid together into a single line.

Equation (4) should be regarded as an empirical relation of limited application. For a value of $u_m = 3.4u_1$ the coefficient for Equation (4) reduces for water to the usual Dittus-Boelter coefficient of 0.023. In the runs reported the extent of the vaporization was sufficient always to yield values of h_{av} larger than those calculated by the single-phase convective heat-transfer equation. The application of Equation (4) is limited further to tests which do not involve the introduction of vapor with the inlet liquid feed.

Equation (4) has been tested by additional data for water and sucrose solutions up to 50%. These data, obtained in the same evaporator and also in an inclined evaporator of similar size (*1, 12*), are plotted in Figure 6 together with the data on the six fluids. Good agreement is shown. The additional water and sugar data are not tests for surface-tension effects nor for tube diameter, but represent further tests of the physical properties of the fluids.

Another series of natural-circulation data is available in which Freon 113 was used in an evaporator loop with an electrically heated, vertical copper tube (*13*). The I.D. was 0.625 in.

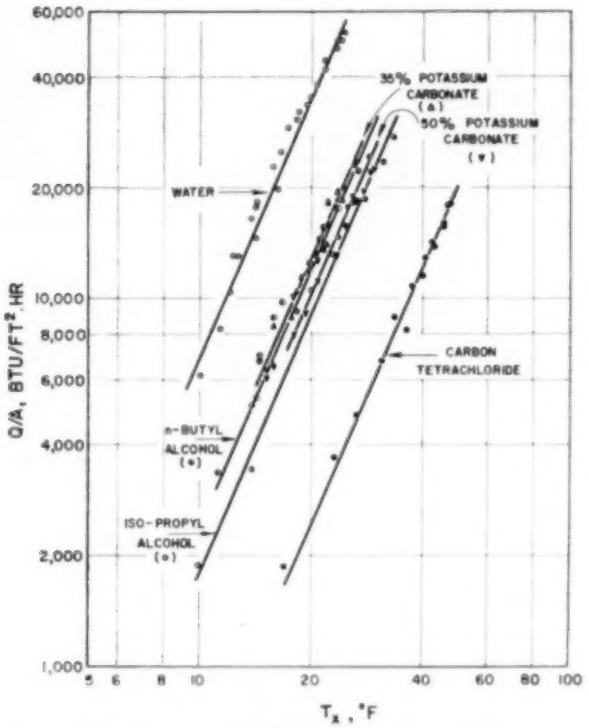

Fig. 4. Heat flux vs. mean liquid temperature drop. Data for six fluids tested at atmospheric pressure in vertical-tube natural-circulation evaporator are presented in the form of total heat flux Q/A vs. T_s. T_s is the mean temperature drop across the liquid film and is equal to average inside wall temperature minus the mean liquid temperature which is taken as the saturation temperature.

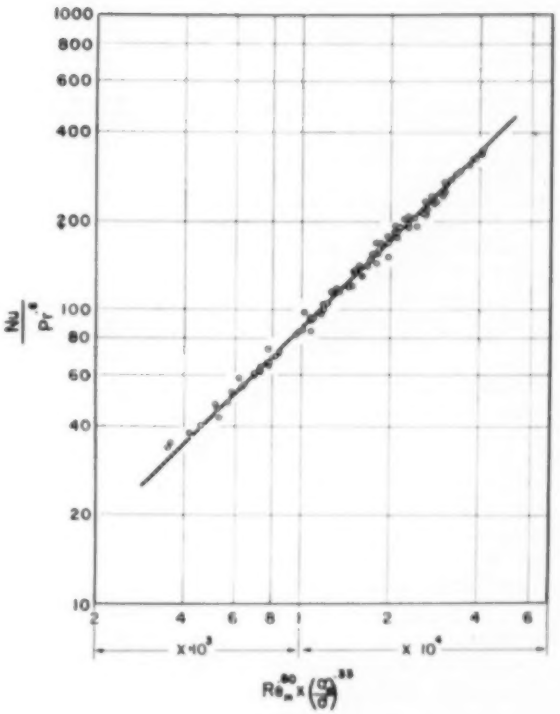

Fig. 5. Correlation of vertical-tube natural-circuation evaporator data for six fluids in 1-in. diam. tube. Test data are correlated for six fluids tested at atmospheric pressure in terms of a Dittus-Boelter-type equation. A log mean velocity is used in the Reynolds number Re_m. The surface tension ratio σ_m/σ, was introduced empirically to bring together the correlations for each fluid into a single line.

and the heated length was 80 in. Heat fluxes were either 5,000 or 10,000 B.t.u./(hr.)(sq.ft.) for each run, and tests were made with runs of various inlet subcooling. Conditions of the tests covered per cent vaporizations from 7 to 70%, and boiling lengths from 1.5 to 5.5 ft. Though Equation (4) is not expected to hold for these conditions, it is interesting to compare the predicted values of h_{ao} with the experimental values calculated only over the boiling length. For seventeen runs with an acid-cleaned surface and a boiling temperature of 150° F., values of h_{ao} by Equation (4) were from 5 to 60% higher than the experimental values, and for seven other runs with an overheated surface and boiling temperatures of 110 and 170° F., values calculated ranged from 70% less to 65% higher than the experimental values.

Boarts, Badger and Meisenburg (2) also reported liquid-film heat-transfer coefficients in their study of a forced convection, vertical evaporator. Water was used at three boiling points, 212, 175, and 140° F., and weight fractions vaporized varied from 0.25 to 5.4%. The test section was a copper tube, 0.76 in. I.D. and 12 ft. long, and steam heated. A correlation also of the Dittus-Boelter type was reported by them for the mean heat-transfer coefficient over the entire tube covering both the nonboiling and boiling sections. It was found that Equation (4) yielded satisfactory agreement of the calculated values of h_{ao} with the few experimental values they reported for the boiling section mean coefficient at atmospheric pressure. At lower pressures and boiling temperatures, however, Equation (4) considerably overestimated the available coefficients.

A relationship involving the log mean velocity for the tests on the six fluids is expressed in Figure 7. With each of the six fluids remaining at atmospheric pressure, the variable tested in the Reynolds modulus Re_m is limited to the log mean velocity. The degree of turbulence in the liquid film is thus reflected by u_m. In the correlation involving the bubble Reynolds number, Equation (2), the tested variable is in turn limited to the heat flux Q/A. A comparison of these two Reynolds numbers indicates that u_m should be a function of Q/A. Such a relation is shown in Figure 7. It will be recognized that Figure 7 is not merely a plot involving vaporization versus heat transfer, for the entering liquid flow rate which varies from run to run, as shown in Figure 3, is used in calculating u_m. Perhaps this functional relationship is the basis for the success of Equation (4) in the present tests.

Pool-Boiling Correlations

The pool-boiling correlation (Equation (2)) has been used as a limiting correlation for surface boiling with forced convection (9). To illustrate this use of the equation, the data for the six fluids are plotted in Figure 8 with the exponents as given in Equation (2). The line representing Addom's water pool-boiling data with platinum wire is also included for comparison with the present data. In this plot the total heat-transfer rate Q/A is used.

This total heat-transfer rate Q/A can be considered to be simply the sum of the contributions $(Q/A)_{conv}$ and by pool boiling $(Q/A)_b$ (9):

$$(Q/A)_b = (Q/A) - (Q/A)_{conv} \qquad (5)$$

Under conditions in which the pool-boiling mechanism predominates, the characteristic length involved in the heat-transfer relations is the mean bubble diameter; whereas at the other extreme in which convection predominates, the characteristic length more probably is the pipe diameter (for flow inside a pipe). This means that the effective film thickness in one case is mainly determined by the disturbances caused by the bubbles forming at the heat-transfer surface and in the other case by the eddy effects across the pipe diameter. For clean pipes of given roughness, liquid-surface effects are important

for pool boiling, but can be neglected when forced convection heat-transfer controls.

To test this simple assumption of superposition, the calculations for $(Q/A)_b$ were carried out for the six fluids with the Dittus-Boelter equation for the convective heat-transfer coefficient and the constant taken as 0.019 instead of 0.023 as recommended by Rohsenow (*9*). The pool-boiling correlation with $(Q/A)_b$ is shown in Figure 9. It is seen that this method of correlation is successful with the present data. Values of the liquid surface constant C_{sf} are given on the figure and fall within the range previously reported. It is probably fortuitous that the water and carbon tetrachloride data fall close to Addom's line. A present difficulty with the pool-boiling correlations is that the value for C_{sf}, though probably relatively independent of pressure, has to be determined empirically for each liquid-surface combination (*9*).

Summary

Two methods of approach to the analysis have been made: one is based upon tube-diameter relations and a log mean velocity, and the other considers the superposition of forced convection and pool-boiling heat transfer. For the conditions of the tests reported, both approaches were successful in correlating the data for the average heat-transfer coefficients. Nevertheless, further studies are required to establish clearly a useful and general correlation in the regions of surface boiling where net evaporation and various degrees of forced or natural convection occur.

The empirical relation found to be particularly effective in correlating the data for the six fluids is

$$\frac{h_{av}D}{k_1} = 0.0086\left(\frac{Du_m\rho_1}{\mu_1}\right)^{0.8}\left(\frac{c_1\mu_1}{k_1}\right)^{0.6}\left(\frac{\sigma_w}{\sigma}\right)^{0.33}$$

A good correlation of the data for each fluid was also obtained by subtracting the calculated convective contribution from total heat flux to obtain the pool-boiling heat flux, and then by using this flux in the pool-boiling equation.

$$\frac{c_1T_s}{h_{fg}} = C_{sf}\left[\frac{(Q/A)_b}{\mu_1 h_{fg}}\sqrt{\frac{g_o\sigma}{g(\rho_1-\rho v)}}\right]^{0.33} Pr^{1.7}$$

Values for C_{sf} for the six fluids are listed in Table A along with values previously reported by Rohsenow (*9*).

Table A.—Pool-Boiling Correlation

Test Data		Evaluations Reported by Rohsenow (9)	
Liquid-Surface Combination	Csf	Liquid-Surface Combination	Csf
Water-copper	0.013	*n*-Pentane-chromium	0.015
Carbon tetrachloride-copper	0.013	Water-platinum	0.013
35% K_2CO_3-copper	0.0054	Benzene-chromium	0.010
n-Butyl alcohol-copper	0.0030	Water-brass	0.0060
50% K_2CO_3-copper	0.0028	Ethyl alcohol-chromium	0.0027
iso-Propyl alcohol-copper	0.0022		

Acknowledgments

The authors wish to express their appreciation to G. H. Montillon, who initiated the research program on natural-circulation evaporator at the University of Minnesota; to W. S. Reveal for the data on the six fluids and the correlation involving the log mean velocity, which he developed. (The latter's research fellowship was sponsored by the Allied Chemical & Dye Corp.); to A. Syverson and D. A. Aubrecht for the additional water and sugar data for both vertical and inclined natural-circulation evaporators; to Antonio Cruz, who prepared the figures and recalculated the data, and to the University of Minnesota Graduate School Grant in Aid of Research for a program covering two-phase flow.

Notation

A = heating surface area, sq.ft.

C_{sf} = coefficient in Equation (2), dependent upon liquid-heating surface combination

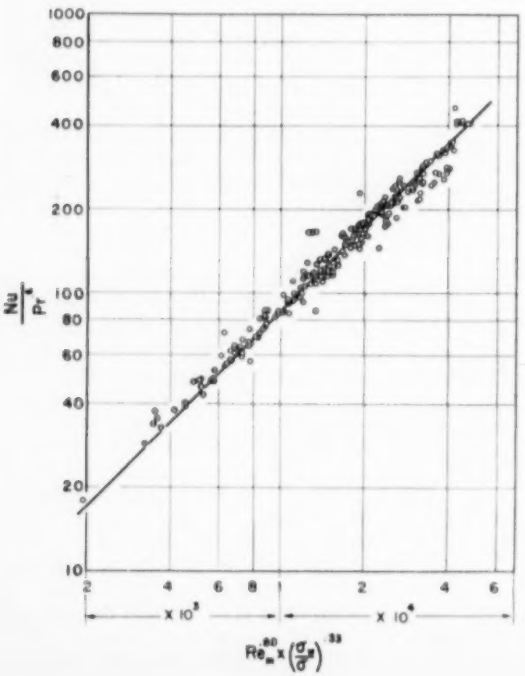

Fig. 6. (Left), Correlation for six fluids and additional water and sugar data in a 1-in. diam. tube. Data of Figure 5 along wtih additional water and sugar data are presented. Additional data are from (*1*, *12*), and represent further tests of physical properties of fluid other than surface tension.

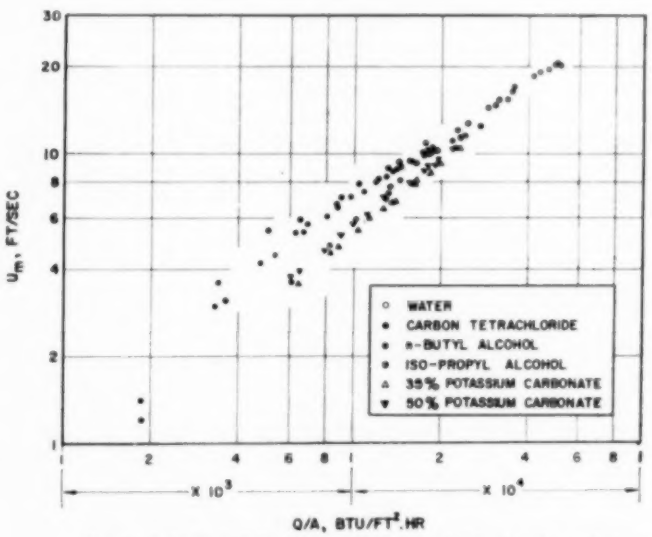

Fig. 7. (Right), Log mean velocity u_m vs. heat flux. The functional relationship between the calculated log mean velocity u_m and the heat flux for each liquid tested is illustrated. u_m is the variable in the Reynolds modulus Re_m for each liquid, and Q/A is the corresponding variable in the bubble Reynolds number Re_b.

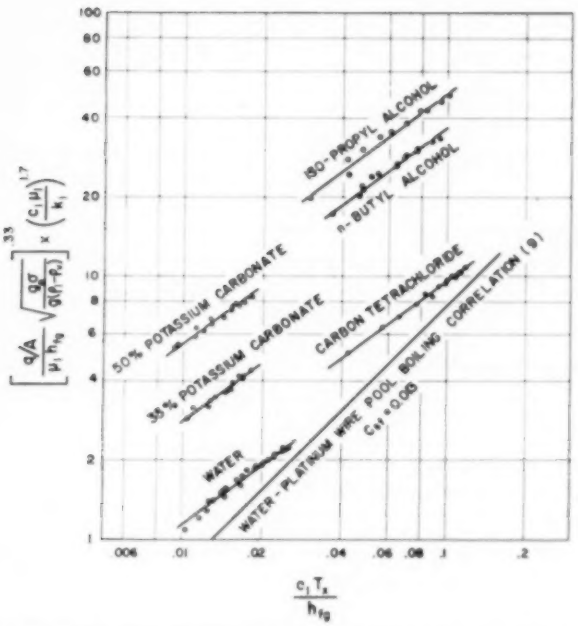

Fig. 8. Pool-boiling correlation with total heat flux, Q/A. The surface-boiling heat-transfer data on six fluids with conditions of net vaporization and induced convection are plotted in the form of the pool-boiling correlation (Equation (2)). The total heat flux is used. Addom's pool-boiling correlation (9) is shown for comparison. At relatively high heat fluxes it is expected that the pool-boiling correlation will hold as a limit for the boiling data with forced or induced convection.

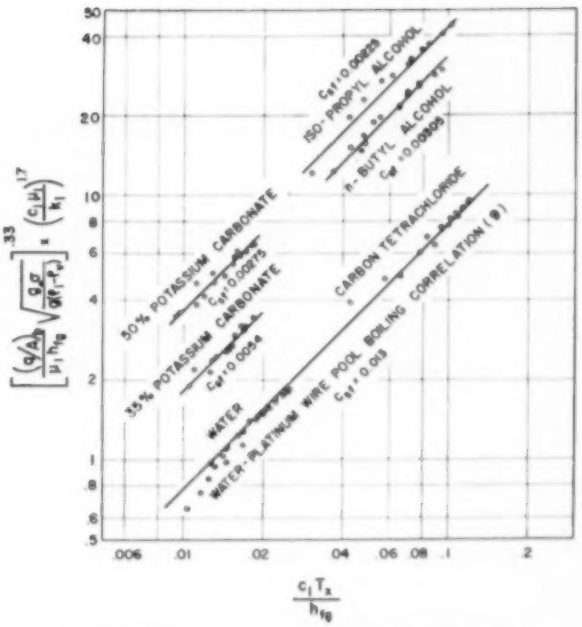

Fig. 9. Pool-boiling correlation with heat flux $(Q/A)_b$. The pool-boiling heat-transfer contribution $(Q/A)_b$ has been calculated for each of the test runs with six fluids and pool boiling correlation, Equation (2), is presented with this value for the heat flux. The pool-boiling coefficients C_{sf} for the liquids are noted.

C_d = constant in bubble diameter equation

c_l = specific heat of saturated liquid, B.t.u./(lb.)(° F.)

D = inside diameter of pipe, ft.

D_b = diameter of vapor bubble leaving the heating surface, ft.

G_b = mass velocity of vapor bubble leaving the heating surface

g = acceleration of gravity

g_c = conversion factor

h = surface-boiling heat-transfer coefficient, B.t.u./(hr.)(sq.ft.)(° F.); h_l, local value; h_{av}, average value over boiling section; $h_{av} = (Q/A)T_s$.

h_{conv} = convection heat-transfer coefficient

h_{fg} = latent heat of vaporization, B.t.u./lb.

n = exponent in equation, $h_l = au^n$

Q/A = heat-transfer rate per unit area of heating surface, B.t.u./(hr.)(sq.ft.) $(Q/A)_b$, calculated pool-boiling heat-transfer rate; $(Q/A)_{conv}$, calculated convective heat-transfer rate $= h_{conv}T_s$

T = thermocouple reading, number subscripts indicate position in Figure 1. T_1 and T_8 are liquid temperatures, T_2 to T_7 are outside wall temperatures. The mean liquid temperature, T_m, is the arithmetic mean of T_1 and T_8, and the average wall temperature, T_4, is the arithmetic mean of T_2 to T_7. T_m is taken as the liquid saturation temperature.

T_s = temperature difference between average temperature of inside wall and saturation temperature of liquid, ° F.; $T_s = T_4 - T_m - \Delta t_p$, where Δt_p is the temperature drop through the pipe wall

u = fluid velocity, ft./sec.; u_1, liquid velocity at pipe inlet; u_2, liquid-vapor mixture velocity at pipe outlet; u_m, log mean liquid-vapor velocity in pipe, $= (u_2 - u_1)/\ln u_2/u_1$. Homogeneous flow assumed

a = proportionality constant in $h_l = au^n$

β = bubble contact angle

σ = surface tension of liquid and vapor interface at liquid boiling point, dynes/cm. and lb./ft.; (σ_w/σ), ratio of surface tension of water to that of fluid, both evaluated at their normal boiling points

ρ_l = density of saturated liquid, lb./cu.ft.; ρ_g, density of vapor, lb./cu.ft.

μ_l = viscosity of liquid, lb./(ft.)(hr.)

Nu = Nusselt number, $h_{av}D/k_l$

Nu_b = bubble Nusselt number, hD_b/k_l

Re_m = modified Reynolds number, $Du_m\rho_l/\mu_l$

Re_b = bubble Reynolds number $(D_bG_b)/\mu_l$

Pr = Prandtl number of liquid, $c_l\mu_l/k_l$

surface boiling—formation of vapor bubbles on the heat-transfer surface

pool boiling—surface boiling with bulk liquid at saturation temperature and no fluid flow

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Distillation Control Problems

application of the McCabe-Thiele diagram

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How McCabe-Thiele diagrams may be used to determine the degree of control attainable with given distillation control systems is shown in this paper, and the basic theory and principles of the diagrams are reviewed.

Four basic control schemes are studied to determine their ability to control a binary distillation as feed composition changes. The method is also applicable in determining the effect of a change in some other variable.

This method of analysis is used to determine the controllability of a column operating with a high reflux ratio. The effect of changing feed composition is studied for two selected control schemes.

This work was undertaken with an arbitrary binary $A-B$ in which A is the light component. The ability of various control systems to control the distillation was determined by the use of McCabe-Thiele diagrams. Equations are presented for the control systems studied. These equations have general utility in solving distillation control problems.

The McCabe-Thiele method is based upon the following equations.

Basic Equations

An over-all material balance for a distillation column gives

$$F = D + W \tag{1}$$

A material balance for the light component gives

$$Fz_F = Dx_D + Wx_W \tag{2}$$

Substituting (1) in (2) gives

$$D = \frac{z_F - x_W}{x_D - x_W} F \tag{3}$$

and

$$W = \frac{x_D - z_F}{x_D - x_W} F \tag{4}$$

Operating Line Equations

An over-all material balance for the rectifying section of a column gives

$$V = L + D \tag{5}$$

and for the light component,

$$Vy_{n+1} = Lx_n + Dx_D \tag{6}$$

Dividing (6) by V, one obtains

$$y_{n+1} = \frac{L}{V} x_n + \frac{D}{V} x_D \tag{7}$$

This is the operating line equation for the rectifying section. Similarly an over-all material balance for the stripping section of a column gives

$$V' = L' - W \tag{8}$$

and for the light component,

$$V'y_{m+1} = L'x_m - Wx_W \tag{9}$$

Dividing (9) by V' gives

$$y_{m+1} = \frac{L'}{V'} x_m - \frac{W}{V'} x_W \tag{10}$$

This is the operating line equation for the stripping section.

q-Line Equation

The quantity q is defined by the equation

$$L' = L + qF \tag{11}$$

The q-line equation, on which the intersection of the two operating lines will fall, is

$$y = \frac{q}{q-1} x - \frac{z_F}{q-1} \tag{12}$$

The coordinates of the point of intersection must then satisfy the equation,

$$y_i = \frac{q}{q-1} x_i - \frac{z_F}{q-1} \tag{13}$$

Since $x_i y_i$ is a point on the two operating lines, its coordinates must also satisfy the following equations

$$y_i = \frac{L}{V} x_i + \frac{D}{V} x_D \tag{14}$$

$$y_i = \frac{L'}{V'} x_i - \frac{W}{V'} x_W \tag{15}$$

Elements of Column Control

A McCabe-Thiele diagram is based on ratios rather than absolute quantities. Though the diagram does not depend upon absolute quantities, the distillation system certainly does. For this reason, "quantity control" is one of the most common types of control found in distillation systems. A distillation system must have quantity control, either directly or indirectly, of at least one of its streams in order to be a determinate system.

The purpose of a distillation may be to produce a given distillate or bottoms purity or both. As operating conditions change, there is a tendency to change the composition of distillate and bottoms. To offset this tendency toward composition change, "composition control" is necessary in the system.

Table 1

Case	Method of Control			Mole Fraction			Moles/Mole of Feed					
	F	L	V'	z_F	x_D	x_W	D	W	L	V	L'	V'
1	..	..	..	0.500	0.925	0.075	0.500	0.500	0.600	1.100	1.600	1.100
2	Quantity	Quantity	Quantity	0.400	0.788	0.012	0.500	0.500	0.600	1.100	1.600	1.100
	Quantity	Quantity	Quantity	0.600	0.954	0.246	0.500	0.500	0.600	1.100	1.600	1.100
3	Quantity	Composition	Quantity	0.400	0.934	0.050	0.396	0.604	0.704	1.100	1.704	1.100
	Quantity	Composition	Quantity	0.600	0.909	0.089	0.623	0.377	0.477	1.100	1.477	1.100
4	Quantity	Quantity	Composition	0.400	0.930	0.086	0.372	0.628	0.600	0.972	1.600	0.972
	Quantity	Quantity	Composition	0.600	0.928	0.063	0.621	0.379	0.600	1.221	1.600	1.221
5	Quantity	Composition	Composition	0.400	0.933	0.085	0.372	0.628	0.618	0.990	1.618	0.990
	Quantity	Composition	Composition	0.600	0.913	0.064	0.631	0.369	0.540	1.171	1.540	1.171
6	..	..	..	0.020	0.750	0.0020	0.024	0.976	1.231	1.255	2.231	1.255
7	Quantity	Quantity	Quantity	0.010	0.389	0.0007	0.024	0.976	1.231	1.255	2.231	1.255
	Quantity	Quantity	Quantity	0.040	0.970	0.0181	0.024	0.976	1.231	1.255	2.231	1.255
8	Quantity	Composition	Quantity	0.010	0.750	0.0013	0.012	0.988	1.243	1.255	2.243	1.255
	Quantity	Composition	Quantity	0.040	0.750	0.0030	0.050	0.950	1.205	1.255	2.205	1.255

These two types of control are those of greatest utility and widest use in distillation systems. They may be used alone or in conjunction with other types of control, such as heat content of a stream or pressure of operation.

For any given binary it is necessary to fix seven variables in order to define a distillation system. Three variables that are usually defined are feed composition, feed quality, and pressure of operation. If, in addition, the system contains a particular column having a fixed number of theoretical plates, it is only necessary—and possible—to fix three other variables in order to define the system.

It is in the control of these three other variables that composition and quantity control find their application. Quantity control must be used for at least one variable in order to define the system. Either composition control or quantity control may be used for each of the other two variables selected for control. Any stream may be selected for quantity control, and any two remaining independent variables may be selected for composition control and/or quantity control.

The many methods for achieving composition or quantity control should not obscure their common objective. For example, composition control may comprise thermal conductivity, specific gravity, infrared, or boiling temperature controllers, in addition to others. Similarly, quantity control of a stream may comprise a flow controller on that stream, such as flow control of the feed to a column. The flow controller might also be on some other stream, such as the approximate quantity control of stripping vapor by flow control of steam to the reboiler. Quantity control could also involve some other type of instrument, such as the approximate quantity control of stripping vapor by a controller which maintained the differential pressure across the column.

The choice of the particular property that is selected as an index of composition or quantity depends upon the degree of variation in that property as composition or quantity changes. However, to the extent that various types of controllers are able to maintain a particular composition or quantity, the effect on the distillation system is the same regardless of the type of controller used.

Control Systems Studied

To serve as a basis for the first control studies in this work, a McCabe-Thiele diagram was developed for an eleven-theoretical-plate column operating with arbitrarily set conditions. This basic design is presented in Case 1 below. Plate 6 is the feed plate. Other diagrams were then developed to show to what extent various control systems could control the column as the feed composition changed from 50 mole % in Case 1 to 40% and 60%. These studies are presented in Cases 2 through 5. For simplicity each of these cases was based on $q = 1.000$. The control systems comprised quantity control of the feed and combinations of the following:

a. Composition control of the liquid on a plate in the rectifying section by varying the amount of reflux.
b. Quantity control of reflux.
c. Composition control of the liquid on a plate in the stripping section by varying the amount of holdup.
d. Quantity control of boilup.

The cases were based upon equilibrium conditions. Equations are presented to aid in using the method for other control problems. The results of all cases are tabulated in Table 1. Case 1 gives the basic design conditions.

Cases 2-5 comprise the following control systems:

Case	Method of Control F	L	V'
2	Quantity	Quantity	Quantity
3	Quantity	Composition	Quantity
4	Quantity	Quantity	Composition
5	Quantity	Composition	Composition

Case 1

The analysis of Case 1 is shown on Figure 1. The following values were set for the variables in this case:

$$q = 1.000$$
$$z_F = 0.500$$
$$x_D = 0.925$$
$$x_W = 0.075$$

Operating lines were then drawn by trial and error so that eleven theoretical steps would fit exactly in the diagram between x_D and x_W. With the diagram fixed, the following quantities were determined by applying the basic equations developed previously:

$$D = 0.500F$$
$$W = 0.500F$$
$$V = 1.100F$$
$$V' = 1.100F$$
$$L = 0.600F$$
$$L' = 1.600F$$

In addition to the basic equations already presented, two other equations were used to derive the general equations for the various cases. They are

$$\text{Slope of rectifying line} = \frac{L}{V} = \frac{x_D - y_i}{x_D - x_i} \qquad (16)$$

$$\text{Slope of stripping line} = \frac{L'}{V'} = \frac{y_i - x_W}{x_i - x_W} \qquad (17)$$

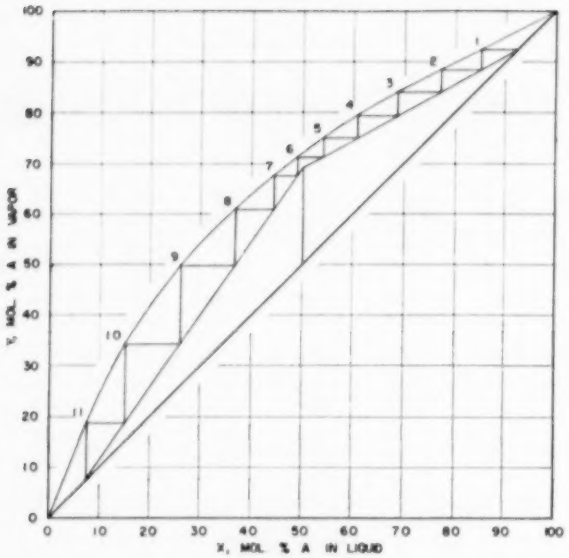

Fig. 1.

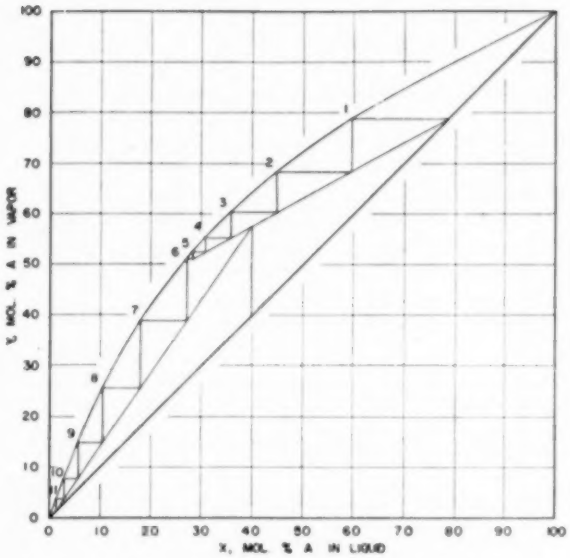

Fig. 2.

Case 2

Control system: F, L and V' are quantity controlled at the Case 1 values. Thus, all other flow quantities are identical to those in Case 1.

By combining Equations (1), (5), (8), (11), and (14), the following expression is obtained for distillate composition:

$$x_D = \frac{V'y_i + (1-q)Fy_i - Lx_i}{V' + (1-q)F - L} \qquad (18)$$

Bottoms composition is obtained by combining Equations (8), (11), and (15):

$$x_W = \frac{(L+qF)x_i - V'y_i}{L + qF - V'} \qquad (19)$$

The procedure for solving this case involves the following steps for each value of z_F and q:

1. Draw the q-line.
2. Assume a value of x_iy_i (which must be on the q-line).
3. Calculate x_D from Equation (18) and draw the rectifying line.
4. Calculate x_W from Equation (19) and draw the stripping line.
5. Draw theoretical steps on the diagram between x_D and x_W.
6. If the diagram contains more or fewer theoretical steps than are available in the column, repeat the procedure, beginning with step 2 and other assumed values of x_iy_i, until the number of theoretical steps available in the column can be exactly fitted into the diagram between x_D and x_W.

Figures 2 and 3 are the diagrams for 40 and 60 mole % feed respectively. With this type of control system, the control of column compositions is poor when feed composition changes. This is not surprising since the controls make no change to counteract the effects of a change in feed composition.

Case 3

Control system: F and V' are quantity controlled at the Case 1 values; the liquid composition on plate 3 (x_3) is controlled at the Case 1 value of 0.680 by varying L.

By combining Equations (4), (8), and (17), the following expression is obtained for bottoms composition:

$$x_W = \frac{x_i(x_D - z_F)F - x_D(y_i - x_i)V'}{(x_D - z_F)F - (y_i - x_i)V'} \qquad (20)$$

The procedure for solving this case involves the following steps for each value of z_F and q:

1. Draw the q-line.
2. Assume a value of x_D.
3. Draw the rectifying line through the assumed x_D by trial and error so that the liquid composition on the control plate (x_4 in this case) falls on the control value when theoretical steps for the rectifying section are drawn in.
4. Read the resulting value of x_iy_i, and calculate x_W from Equation (20).
5. Draw the stripping line and the theoretical steps for the stripping section.
6. Repeat the procedure beginning with step 2 until the number of theoretical steps on the diagram is equal to the number available in the column.

Figures 4 and 5 are the diagrams for 40 and 60 mole % feed respectively. For 40 and 60 mole % feed, x_D is 0.934 and 0.909, and x_W is 0.050 and 0.089 respectively.

Uitti (2) investigated similar cases, but as he varied z_F, he maintained the feed plate composition equal to the feed composition. The result was an unavoidable variation in V', one of the variables that he wished to keep constant. For example, if the values given in Figure 5 (2) are analyzed by the basic equations presented here, it is seen that V'/F changed from approximately 1.38 for 75 mole % feed to approximately 1.89 for 40 mole % feed. He attributed this change in V'/F to a change in the heat balance around the column, but actually it resulted from selecting feed plate composition as one of the variables fixed. Obviously, as the feed composition changes, there will be no control of feed plate composition unless a controller is used for this specific purpose.

Case 4

Control system: F and L are quantity controlled at the Case 1 values; the liquid composition on plate 9 (x_9) is controlled at the Case 1 value of 0.259 by varying V'.

By combining Equations (3), (5), and (16), the following equation for distillate composition is obtained:

$$x_D = \frac{x_W(y_i - x_i)L - y_i(z_F - x_W)F}{(y_i - x_i)L - (z_F - x_W)F} \qquad (21)$$

The steps for solving this case are as follows:

1. Draw the q-line.
2. Assume a value of x_W.
3. Draw the stripping line by trial and error so that the liquid composition on the control plate (x_9 in this case) falls on the control value when theoretical steps for the stripping section are drawn in.

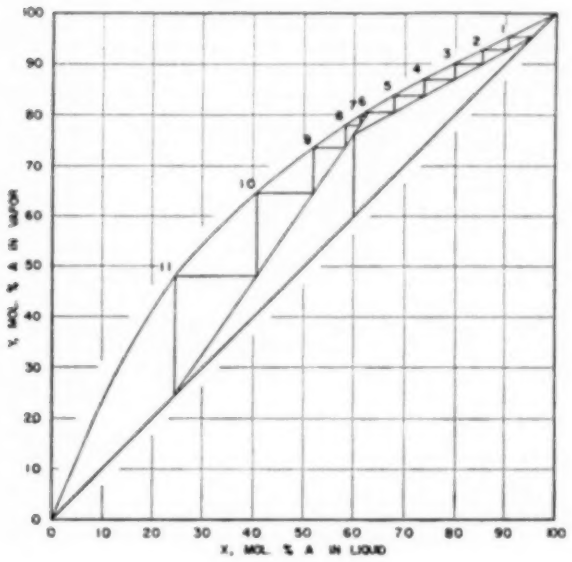

Fig. 3.

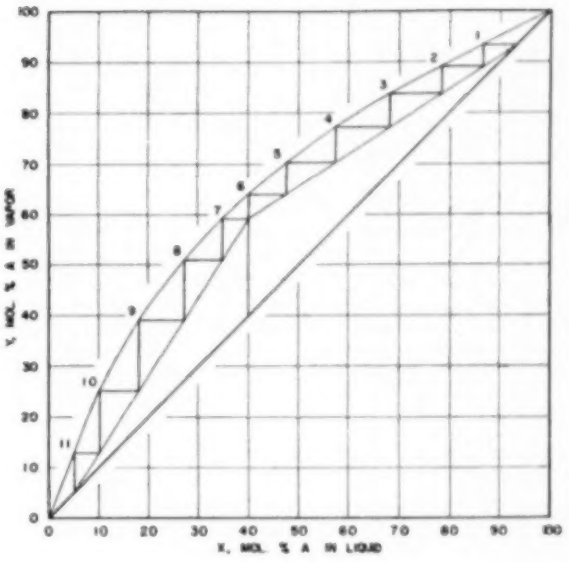

Fig. 4.

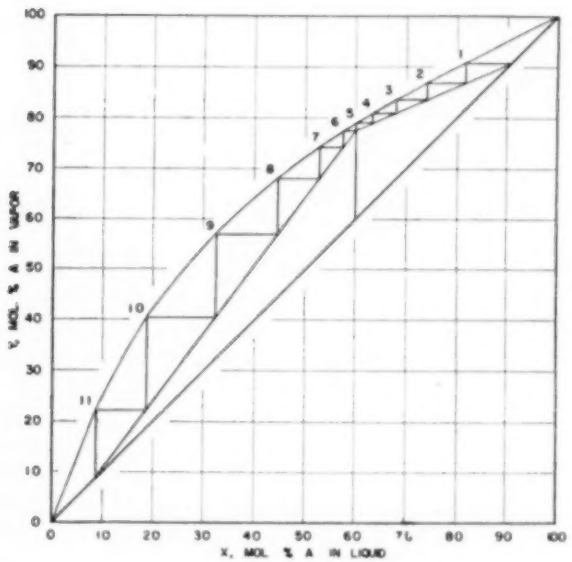

Fig. 5.

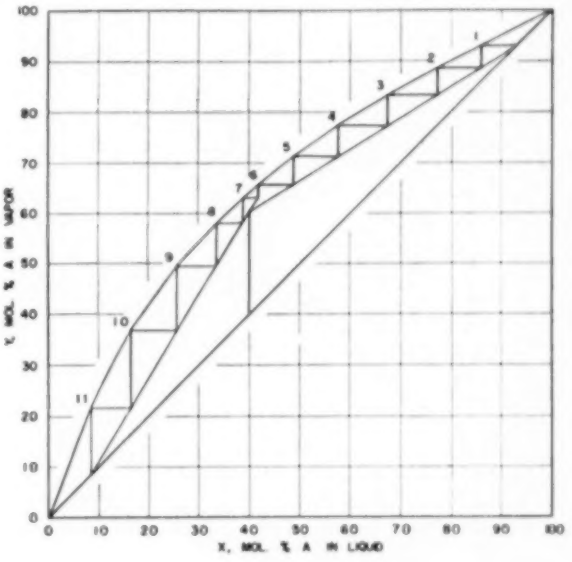

Fig. 6.

4. Read the resulting value of x_1y_1, and calculate x_D from Equation (21).
5. Draw the rectifying line and the theoretical steps for the rectifying section.
6. Repeat the procedure beginning with step 2 until the number of theoretical steps on the diagram is equal to the number available in the column.

Figures 6 and 7 show the results of this case. For 40 and 60 mole % feed, x_D is 0.930 and 0.928, and x_W is 0.086 and 0.063 respectively.

Case 5

Control system: F is quantity controlled at the Case 1 value; the liquid compositions on plates 3 (x_3) and 9 (x_9) are controlled at the Case 1 values by varying L and V'.

With this control system the solution requires graphical trial and error, and does not involve the use of equations. A trial value of x_D, x_W or x_0y_1 may be used as the starting point. The following procedure utilizes a trial value of x_0y_1.

1. Draw the q-line.
2. Assume a value of x_1y_1.
3. Draw the rectifying line by trial and error through x_1y_1 so that the liquid composition on the control plate (x_3 in this case) will fall on the control value when the theoretical steps for the rectifying section are drawn in.
4. Draw the stripping line by trial and error through x_1y_1 so that the liquid composition on the control plate (x_9 in this case) will fall on the control value when the theoretical steps for the stripping section are drawn in.
5. Repeat the procedure beginning with step 2 until the number of theoretical steps on the diagram is equal to the number available in the column.

Figures 8 and 9 show the results of this case. For 40 and 60 mole % feed, x_D is 0.933 and 0.913, and x_W is 0.085 and 0.064 respectively.

Application to High Reflux Ratio Operation

There is a widely held belief that in a column operating with a high reflux

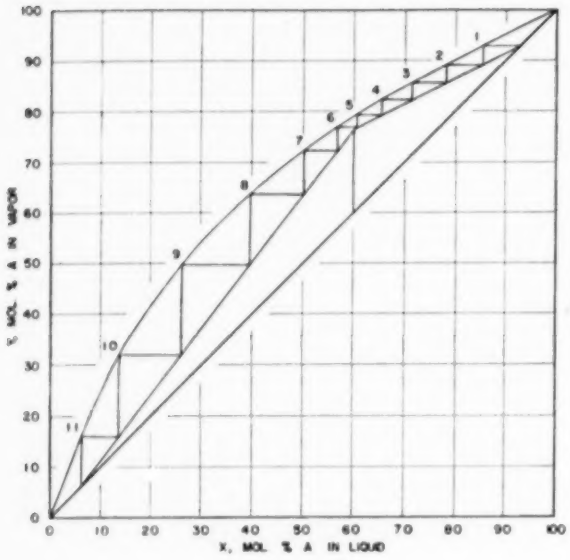

Fig. 7.

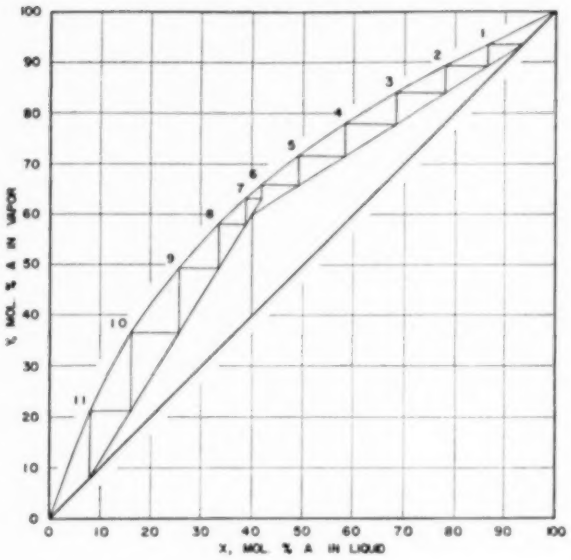

Fig. 8.

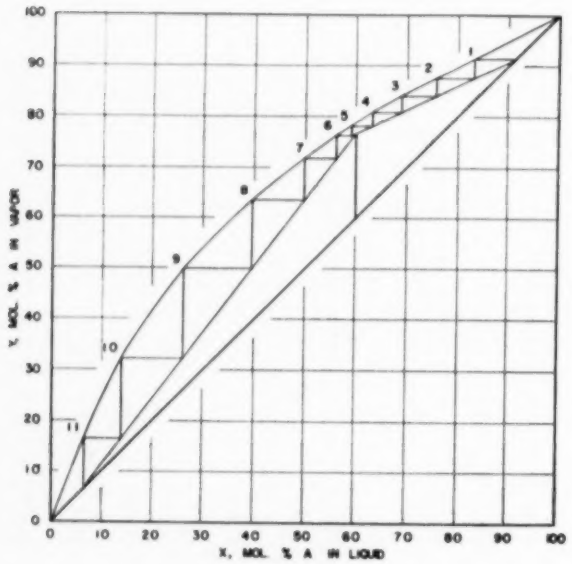

Fig. 9.

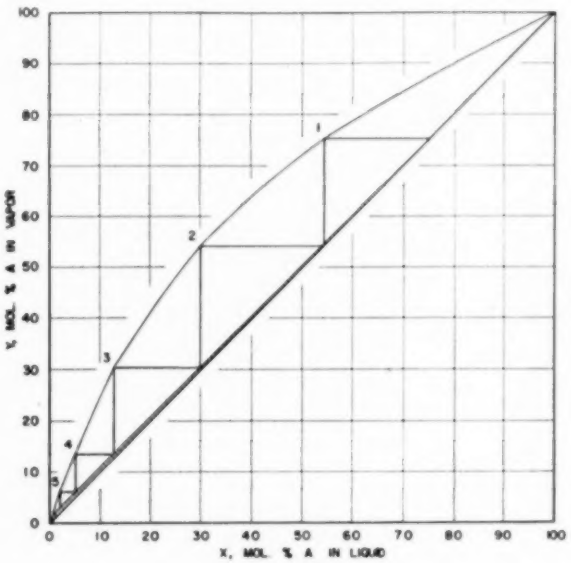

Fig. 10a.

ratio, control, by varying the reflux, is impractical since the rectifying line is so close to the 45° line. The Cases 6 through 8 were developed to show the fallacy in this belief. These three cases are based on a ten-theoretical-plate column. Plate 6 is the feed plate. As before, q was set at 1.000 for simplicity. Case 6 was based upon an arbitrarily defined separation with a 2 mole % feed. Cases 7 and 8 show the effect of changing the feed composition to 1 and 4 mole % with the following control systems:

	Method of Control		
Case	F	L	V'
7	Quantity	Quantity	Quantity
8	Quantity	Composition	Quantity

Case 6

Case 6 is shown in Figures 10*a* and *b*. The following values were set for the variables in this case:

$$q = 1.000$$
$$z_F = 0.020$$
$$x_D = 0.750$$
$$x_W = 0.0020$$

With the diagram fixed, the following quantities were determined by applying the basic equations developed previously:

$$D = 0.024F$$
$$W = 0.976F$$
$$V = 1.255F$$
$$V' = 1.255F$$
$$L = 1.231F$$
$$L' = 2.231F$$

Case 7

This case shows the effect on column conditions of changing the feed composition to 1 and 4 mole %. No offsetting change is made by the column controls since there is quantity control of F, L and V' at the values existing in Case 6. This case is analogous to Case 2 and is solved by the procedure given for that case.

Figures 11*a* and *b* show the diagram for 1 mole % feed, and Figure 12 shows the diagram for 4 mole % feed. Over this range of feed composition, x_D varies from 0.389 to 0.970, and x_W varies from 0.0007 to 0.0181.

Both the leaner and richer feeds result in a composition gradient change which would enable a composition controller to make an offsetting correction. Case 8 illustrates the effectiveness of this type of control for the two feed compositions.

Case 8

Control system: F and V' are quantity controlled at the Case 6 values; the distillate composition (x_D) is controlled at the Case 6 value by varying L.

This case is analogous to Case 3. The solution involves the following steps:

1. Draw the q-line.
2. Assume a value of x_1y_1.
3. Calculate x_W from Equation (20) using the control value of x_D.
4. Draw the two operating lines and the theoretical steps for the separation.
5. Repeat the procedure beginning with step 2 until the number of theoretical steps on the diagram is equal to the number available in the column.

For the 1 mole % feed (Figures 13*a* and *b*), x_W has increased from 0.0007 in Case 7 to 0.0013 in the present case, and x_D has increased from 0.389 to the control value of 0.750. Similarly, for 4 mole % feed (Figures 14*a* and *b*), x_W has decreased from 0.0181 to 0.0030, and x_D has decreased from 0.970 to 0.750. This shift in the composition gradient and in the resulting values of x_D and x_W contributes greatly to controllability even when the operating lines approach the 45° line.

Summary

This work shows that the best control system depends upon the particular case and objectives involved. One control system may minimize the variation in distillate composition, and another may minimize the variation in bottoms composition. Each control problem must be analyzed to determine the best control system.

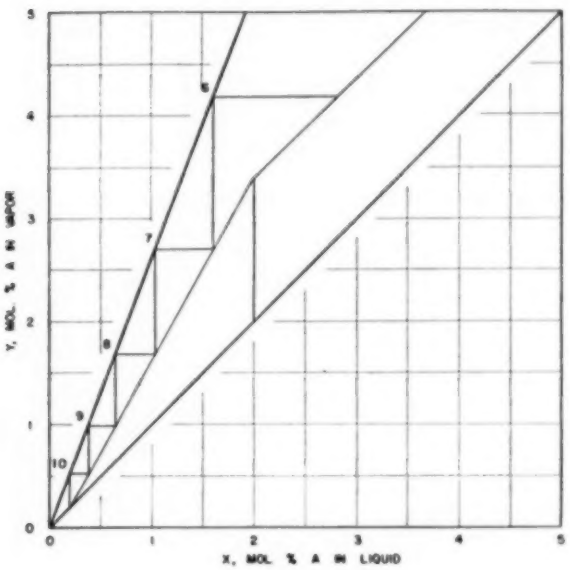

Fig. 10b.

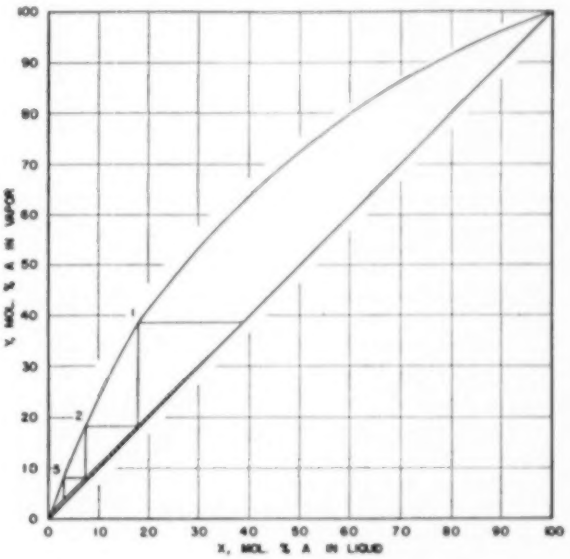

Fig. 11a.

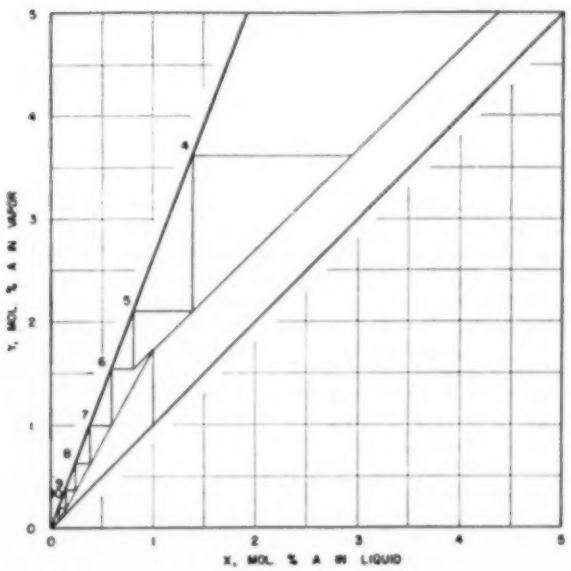

Fig. 11b.

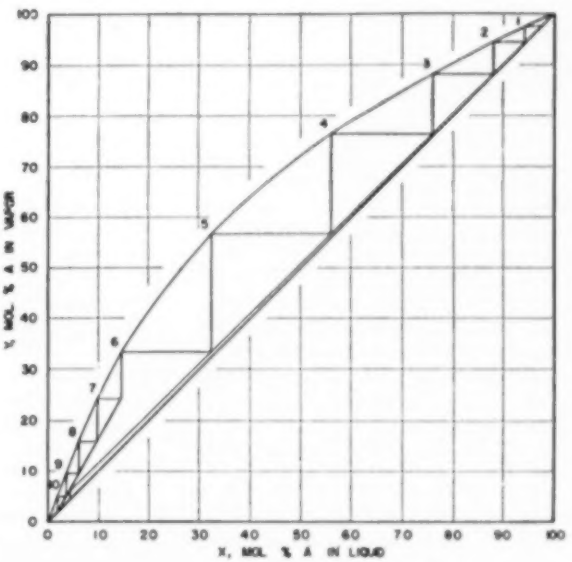

Fig. 12.

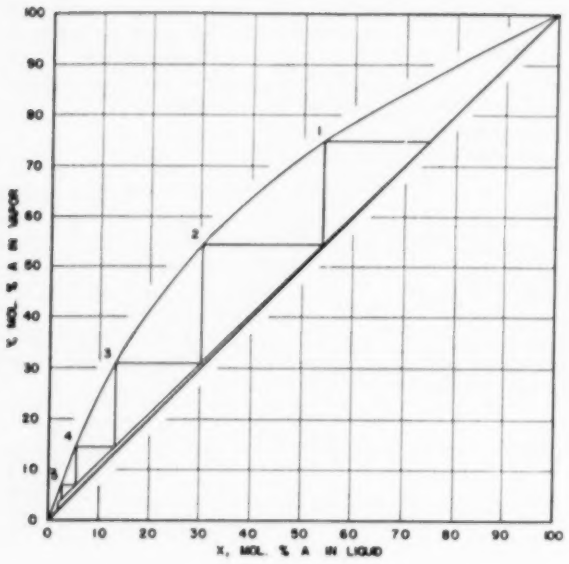

Fig. 13a.

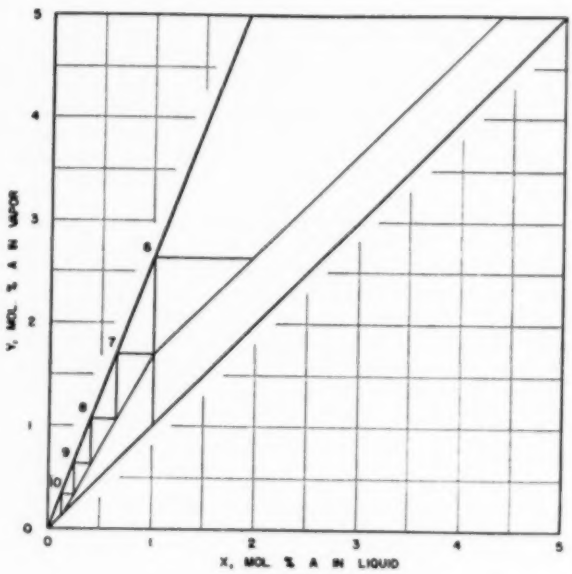

Fig. 13b.

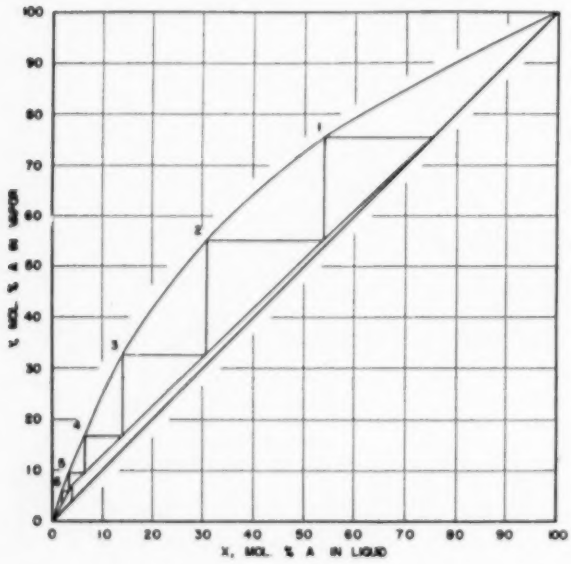

Fig. 14a.

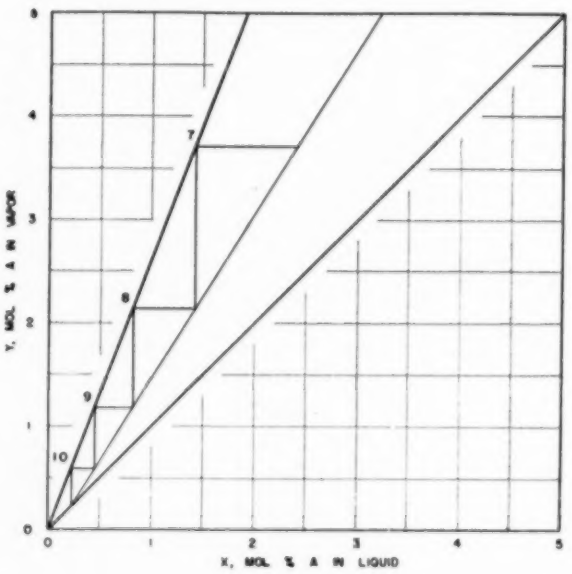

Fig. 14b.

Notation

D = moles of distillate per unit of time

F = moles of feed per unit of time

f = feed plate

L = moles of liquid downflow in the rectifying section per unit of time

L' = moles of liquid downflow in the stripping section per unit of time

m = a plate in stripping section

N = number of theoretical plates in a given distillation column

n = a plate in rectifying section

q = moles of liquid downflow in stripping section resulting from the introduction of one mole of feed

V = moles of vapor upflow in the rectifying section per unit of time

V' = moles of vapor upflow in the stripping section per unit of time

W = moles of bottoms per unit of time

x_D = mole fraction of light component in distillate

x_i = x coordinate of intersection of operating lines with q-line

x_m = mole fraction of light component in liquid leaving plate m in the stripping section

x_n = mole fraction of light component in the liquid leaving plate n in rectifying section

x_W = mole fraction of light component in bottoms

y_i = y coordinate of intersection of operating lines with q-line

y_m = mole fraction of light component in vapor leaving plate m in stripping section

y_n = mole fraction of light component in vapor leaving plate n in rectifying section

z_F = mole fraction of light component in the feed

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2. Uitti, K. D., *Petroleum Refiner*, **29**, 130 (1950).

The Increase in Corporation Patent Work

W. C. Asbury and J. K. Small Standard Oil Development Company, New York

The total number of patents granted each year in the United States has varied a good deal because of war and economic cycles, but has generally ranged between 40,000 and 50,000 patents a year since 1913 except for a temporary dip due to World War II. Considering the patents listed in *Chemical Abstracts* as the total patents on chemical subjects granted each year, Fleischer (*1*) reports that chemical patents have increased from about 6% of the total United States patents issued during the years 1915-1924 to about 20% of those issued during 1940-1950. The increase of chemical patents has thus been more than threefold in the past thirty years. More than seven thousand chemical patents were granted by the Patent Office in 1951.

Information on the practice of patent attorneys is difficult to get as these men are widely scattered through corporations and law firms, and the U. S. Patent Office has not published any analysis of the nature of the practice or the technical degrees of the men licensed to practice before it. A survey therefore of the patent attorneys of several leading corporations engaged in chemical and petroleum manufacturing operations in this country offers representative experience even though these attorneys are only a small portion of the total engaged in chemical patent practice.

TEN COMPANIES—CHEMICAL OR PETROLEUM

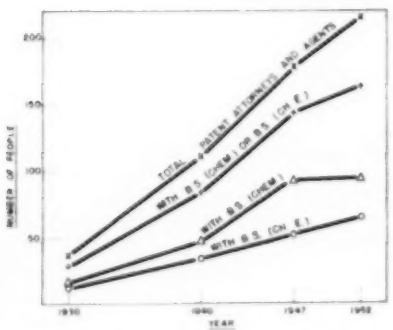


Fig. 1. Patent attorneys and agents.

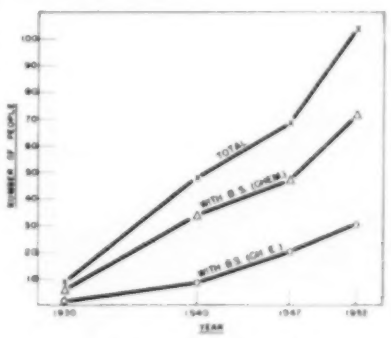


Fig. 2. Patent liaison.

Table 1

PATENT ATTORNEYS AND AGENTS

10 Companies—Chemical or Petroleum

	Total	B.S. (Chem.) Chemical	B.S. (Ch.E.) Chemical Engineers	(2) + (3)	% of total
	(1)	(2)	(3)	(4)	(4)/(1)
1952	215	94	67	161	75
1947	179	93	51	144	80
1940	110	47	35	82	75
1930	36	16	13	29	81
				Average	78

Table 2

PATENT LIAISON

10 Companies—Chemical or Petroleum

	Total	B.S. (Chem.) Chemical	B.S. (Ch.E.) Chemical Engineers	(2) + (3)	% of total
	(1)	(2)	(3)	(4)	(4)/(1)
1952	104	72	30	102	98
1947	69	47	20	67	97
1940	48	34	8	42	87
1930	9	6	3	9	100
				Average	95

Figure 1 and Table 1 indicate a steady growth in the total number of patent attorneys and registered patent agents in these corporations. There has also been steady growth for those having a bachelor of science degree or equivalent in chemical engineering or chemistry, although this group has not increased quite so rapidly in the last five-year period, possibly because of the general shortage of technical graduates. The new chemical engineers in the last five years have outnumbered the new chemists in this work. This is probably due both to the increasing number of chemical engineering graduates in this country since 1930 and to the increasing scale of chemical manufacturing operations.

At any rate, the total increase of attorneys and agents in these corporations since 1930 has been sixfold, while the increase of attorneys having degrees in either chemical engineering or chemistry has been more than fivefold.

Figure 2 and Table 2 give similar data on those engaged in the patent liaison work of these same companies. Here the increase has been about ninefold, and almost every one of these people has a degree in chemical engineering or chemistry. This field can be expected to continue its growth.

The Patent Office also increased the number of its examiners in the divisions handling chemical inventions from 70 examiners in 1930 to 121 examiners in 1951, or from 12.5% of the total examining staff in 1930 to 15.2% in 1951.

Literature Cited

1. Fleischer, Joseph, *Advances in Chem. Ser.* No. 4, 61 (1951).

Abstracted from a talk presented at the Forty-fifth Annual Meeting in Cleveland.

Cost Estimation

fabricated plate equipment

James Donovan Artisan Metal Products, Inc. Waltham, Massachusetts

Equipment costs can often be materially influenced by early attention to certain details. In this paper author Donovan, who is not only a chemical engineer but also an equipment fabricator and estimator of costs, endeavors to give the reader the benefit of his manys years of observations and experience.

A comprehension and understanding of costs should be an integral part of an engineer's very nature. It is the essence of engineering to do an economical job—to product an optimum result. Thus, costs are involved in nearly all engineering decisions, and, in order to do an intelligent job of engineering design at any level, it is essential that the cost factor always be remembered.

That costs are a factor at all points may be expressed in another way by saying that all designs should be made with the cost element in mind at the time of design—not after the design has been determined and submitted for bids. It is also essential to good design that cost be closely followed as one works out the details; hence the subject here is concerned with the interrelation of costs and design as well as the presentation of certain techniques of cost estimation.

Of course this paper cannot be a complete exposition on cost estimation of chemical engineering equipment. Rather it is a basic presentation of the elements and techniques involved in practical cost estimation of *fabricated* equipment.

Relationship of Cost to Design

Most design engineering culminates in a series of drawings and specifications, and it is during the development of these that the design engineer should be cost conscious in his designing and specifying economical equipment.

Everyone knows that more than first cost is involved, but many people forget that the major cost from the point of view of equipment is maintenance. Maintenance considerations, apart from corrosion problems, have contributed to the widening use of such materials as stainless steels. For instance, electric-power companies have found it more economical to purchase a slightly lighter gauge stainless-steel transformer tank for pole installation than to purchase those made from mild carbon steel, which must be protected by galvanizing and then by paint. The mild carbon-steel tanks must be repainted every few years, and the cost of doing a paint job at the top of a pole is appreciable. Stainless-steel transformer tanks do not require this kind of maintenance; hence are more economical, although the initial cost is higher.

Every element of design affects cost—size, shape, metal, type of welding, finish, etc. The last-named is a specification frequently omitted on drawings. In welded construction alone, a piece of

Table 1.—Cost (In Dollars) of 100 Square Feet of Tubing

(outside surface)

Size of Tubes	304 S.S.		316 S.S.		Nickel	Aluminum	Copper	Admiralty	Steel	
	S	W	S	W	S	S	S	S	S	W
¾-in. 18 gauge 510 lin. ft.	$ 438	$ 387	$ 703	$ 482	$ 443	$ 219	$ 191	$ 140	$ 116	$ 85
1-in. 16 gauge 382 lin. ft.	478	439	767	573	451	290	233	181	112	76
2-in. 16 gauge 191 lin. ft.	500	455	802	631	520	315	243	210	96	69

Notes:
S—Seamless Drawn.
W—Welded.
Prices as of March 25, 1954.

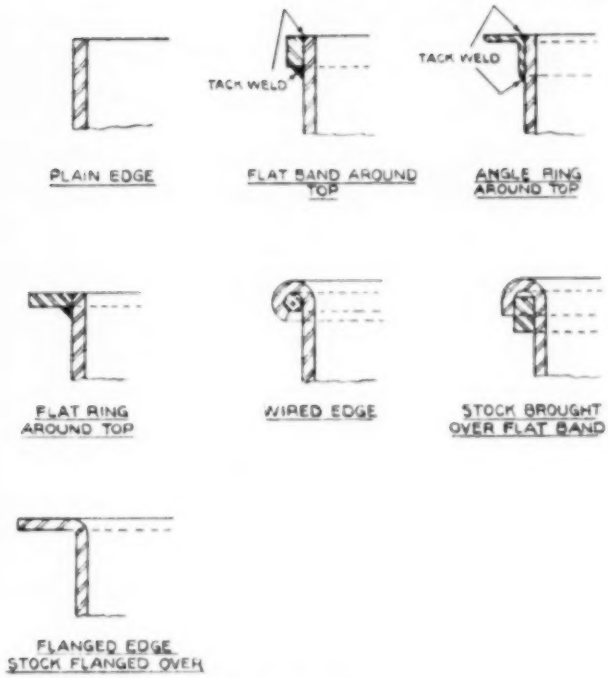


Fig. 1a. Top details.

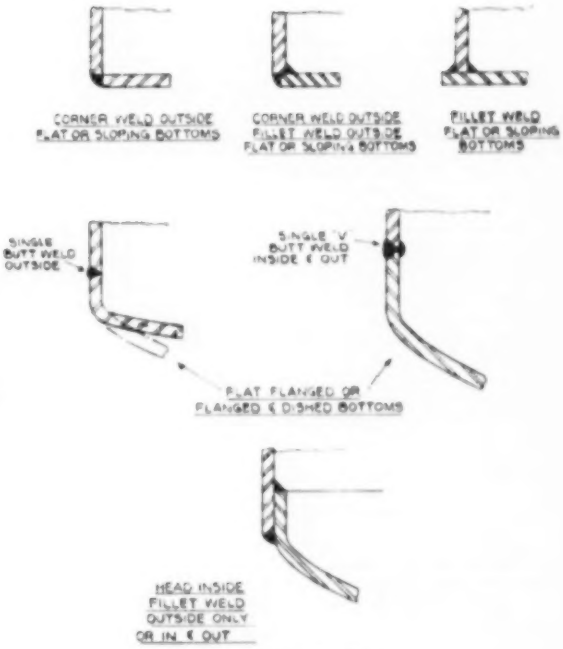


Fig. 1b. Bottom details.

equipment may be finished in the following progressive steps:

As welded
Weld spatter removed
Welds ground smooth
All inside surfaces polished
Passivated
Painted

Much competitively priced equipment has the weld spatter left on, which leads to difficult and imperfect painting, to say nothing of the ruining of expensive brushes, increased frequency of painting, and poor appearance in the welded areas.

Figure 1 (a, b) shows typical details of construction of a simple tank. Each of the design features carries a difference in cost and a difference in value. The factors involved in this respect need not be mentioned here. It is, however, the writer's experience that many engineers do not think this problem through carefully and arrive at an economical answer for their own specific requirements. For example, if a ring is specified as a finish around the top of a tank, there is rarely any specification concerning the method of welding the ring to the tank—should it be tacked both top and bottom, welded both top and bottom, or, perhaps welded on the top and tacked on the bottom?

The use of clad material frequently comes up for consideration. There are certain excellent applications for clad material, especially where heat transfer through the metal is a factor, and on heavy equipment. If there is substantially no corrosion, and the thin coating of metal will last far beyond the possible useful life of the equipment, then a

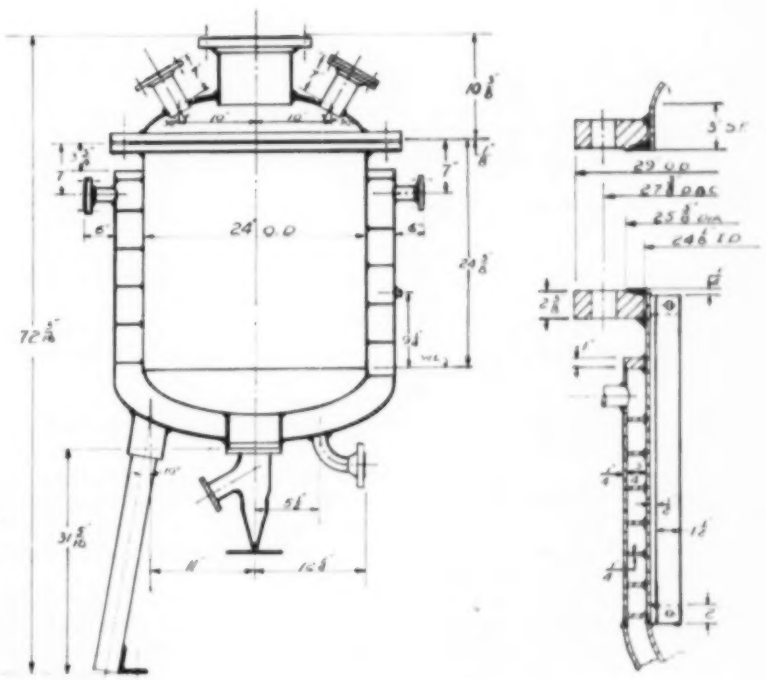


Fig. 2. Cross section of 24-in. diam. vessel.

Table 2.—Comparison of Price and Mechanical Properties of Various Metals † ‡

Material	Composition—%	Ultimate Tensile Strength‡ lb./sq.in.	Plate lb. 100	Plate lb. 1000	Sheet lb. 100	Sheet lb. 1000	Tubing lb. 100	Tubing lb. 1000	Ratio of Plate Steel = 1.0
		Form & Price at Warehouse							
Flange quality Steel A-285 Gr.C	carbon . 30-35, mang. . 80, phos. 04-05, sulfur . 05, copper . 35, balance—iron	55,000	.09	.07	.10	.07	.67	.48	1.
304 S.S.	chrome 18-20, nickel 8-10, carbon . 08 max., balance—iron	75,000	.58	.49	.67	.58	2.09	1.70	7.
316 S.S.	chrome 16-18, nickel 10-14, carbon . 10 max., moly. . 2-3, balance—iron	75,000	.77	.68	.82	.73	3.09	2.19	9.72
316 S.S. e/c	similar to 316 S.S. but with .03 carbon max.	75,000	.82	.73	.88	.78	....	....	10.43
304 S.S. clad	304 S.S.—20 steel 80	55,000	.45	.37	....	....	....	....	5.3
316 S.S. clad	316 S.S.—20 steel 80	55,000	.50	.42	....	....	....	....	6.
Nickel	nickel 99.4	70,000	1.00	.87	1.12	.88	1.93	1.72	12.4
Monel	nickel 67, copper 30, iron 1.4, mang. 1.0	75,000	.81	.68	.93	.73	1.79	1.58	9.72
Inconel	nickel 79.5, chromium 13, iron 6.5	85,000	1.06	.93	1.18	.98	2.18	1.93	13.3
Nickel clad	nickel 20 steel 80	55,000	.64	.55	....	....	....	....	7.86
Monel clad	monel 20 steel 80	55,000	.65	.56	....	....	....	....	8.
Inconel clad	inconel 20 steel 80	55,000	.74	.66	....	....	....	....	9.4
Hastelloy "C"	moly. 19, chromium 17. iron 6, mang. 6, silicon, tungsten, balance—nickel	122,000	3.00	2.75	3.36	3.08	6.00	5.22	39.3
2 S. Alum.	aluminum 99 plus	13,000	.62	.42	.74	.42	.95	.84	6.
52 S. Alum.	mang. 2.5, chromium .25, balance—aluminum	31,000	.66	.45	.80	.46	1.30	1.23	6.43
Copper	copper 99.9 plus	32,000	.68	.52	.68	.52	.88	.62	7.43

Notes:
S.S. Plates annealed & pickled finish.
S.S. sheet, 2B finish; clad plates annealed & descaled finish.
Monel, inconel & nickel plates annealed & sandblasted finish.
Hastelloy, copper & alum annealed. Mild steel, open hearth. Sheet, stock sizes. Tubing based on 1-in. O.D. size.
All prices in dollars and cents.

‡ Ultimate tensile strength as given above is the average usually used.

† Prices as of Feb. 23, 1954.

saving of twenty per cent is certainly worth while. In purchasing and specifying clad material, however, one should be more careful to call for quality fabrication and rigid inspection. It is more difficult to do a perfect job on clad material, and it is more expensive to fabricate owing to more elaborate construction and welding procedures.

Vessels designed for either internal or external pressure should be designed in general conformance with the A.S.M.E or A.P.I.-A.S.M.E. Code for unfired pressure vessels. In some cities and states it is mandatory that vessels be so designed. Code construction, with code inspection and stamping, costs more than noncode—possibly ten per cent in the average case. This is due to detailed engineering requirements, inspection fees, and procurement of code materials.

Estimating Individual Pieces of Fabricated Equipment

Generally speaking, what one desires is a selling price for a specific piece of equipment rather than the cost thereof. The usual method of determining selling price is to estimate the cost and then apply a markup which may vary with a number of situations. One sound way to develop cost is as follows.

1. Have the mechanical detail of the design complete.
2. List materials, price these.
3. List various labor items, price these.
4. Apply various markups.

The materials cost is relatively straightforward to determine. One takes off a bill of material in such form as to give areas, lengths or volumes and then applies to them the unit weight factors, some of which all engineers should have in their heads, but may have to obtain from handbooks, stock lists, and other sources. The accuracy required for most engineering cost calculations does not justify anything beyond two significant figures; hence if an engineer remembers the following few weights, he may, by mental arithmetic, determine the necessary factors:

Steel, stainless, nickel, etc., ¼-in. plate weighs 10 lb./sq.ft.
¼-in. copper plate weighs 12 lb./sq.ft.
¼-in. aluminum plate weighs 3.5 lb./sq.ft.

From this it is easy to see that one square foot of 1/16 stainless sheet would weigh 2½ lb., ⅛ in. would weigh 5 lb., etc. This applies to steel and comparable materials.

Bar stock is most readily estimated by taking the weight per square foot of thickness for any material and mentally taking a fraction thereof proportionated to the width of the bar stock.

Tubing is readily approximated by mentally calculating its girth, dividing this by 12 to give the number of square feet per linear foot, and applying this factor to the weight per square foot. Since some however would like to have a few tubing sizes and weights available for perhaps more accurate and easier figuring, some of the more normal sizes and weights are listed in Table 1.

In estimating round stock, it is relatively easy to calculate the number of cubic inches and apply the factor of weight per cubic inch. In the case of steel this is substantially ¼ lb./cu.in.

The price per pound of material varies according to the quantities involved. Table 2 presents a series of prices as of Feb. 23, 1954, for materials commonly used in manufacturing chemical plant equipment, with price per pound given on the basis of either 100-lb. or 1,000-lb. quantity. These prices are generally the equivalent of what may be called "warehouse prices" applied to the normal-sized pieces going into the great majority of chemical engineering equipment. In those instances where large and heavy pieces are to be used, or where multiple pieces of the same size are to be used, the price will be slightly lower, but except for the case of plain steel, there is hardly any appreciable difference in the estimate of price. Plain steel plate may be bought for something near 5 cents/lb. in large quantities, and in plain tank form sells, fabricated, for 10 cents/lb.

Tensile strength, modulus of elasticity, and density are factors of importance in the economical design and utilization of metal and should be considered in the making of selections.

ARTISAN METAL PRODUCTS, INC.
BOSTON 24, MASS.

BILL OF MATERIALS — 24" ESTERIFICATION KETTLE

DATE 8/24 1120-1 JOB # 1395 MADE BY J. J. W. CHECKED BY

ITEM	QUAN.	MATERIAL	DESCRIPTION	NOTE TO	Weight	Unit Price	COST
1.	1	316 S. S.	Plate 1/4" x 28" x 76" Roll	Shell	132 #	.80	106.00
2.	1	316 S. S.	Plate 1/4" x 30" x 60" Cir. & Form	Heads	130 #	1.07	139.00
3.	1	316 S. S.	Plate 3/16" x 4" x 32" Roll	Neck	9 #	.88	8.00
4.	1	316 S. S.	Plate 1-3/4" x 8" x 8" Mach.	Pad	33 #	.85	30.00
5.	1	316 S. S.	Pipe 2" x 8"	Nozzle	3 #	11.36/#	10.00
6.	1	316 S. S.	Pipe 3" Sch. 40 x 9" lg.	Nozzle Reinforcing	6 #	22.00/#	12.00
7.	1	316 S. S.	Plate 5/16" x 18" x 18"	Pad	30 #	.85	27.00
8.	1	316 S. S.	Pipe 3/4" Sch. 40 x 8" lg.	Nozzle	1 #	4.27/#	5.00
9.	1	316 S. S.	Male Flange 2-1/2" 150# Tongue & Groove Facing	T & G Flg.	14 #	20.00	20.00
10.	1	316 S. S.	Male Flange 3" 150# Tongue & Groove Facing	T & G Flg.	18 #	35.00	35.00
11.	1	316 S. S.	Male Flange 1" 150# Tongue & Groove Facing	T & G Flg.	4 #	15.00	15.00
12.	1	316 S. S.	Flat Bar 1/4" x 1-1/2" x 15"	Baffles	11 #	.86	9.00
13.	8	316 S. S.	Hex Bolts & Nuts 1/8" x 1"	B & N	1 #		2.00
14.	1	316 S. S.	Tube 1-1/2" x 8"	Nozzle	1 #		6.00
15.	1	316 S. S.	Male Flange 1 1/2" Spec. Tongue & Groove	T & G Flg.	5 #	20.00	20.00
16.	2	Steel	Forged Rings 28" OD x 24 1/4" ID x 2 3/4" thick	Flanges 24"150#	312 #		150.00
17.	1	Steel	Plate 1/4" x 21" x 52" Roll	Shell	133 #		14.00
18.	1	Steel	Plate 1/4" x 32" x 32" Cir. & Form	Head 24"150#	72 #		8.00
19.	1	Steel	Bar 1" x 1" x 56" lg. Roll	Ring	10 #		1.00
20.	1	Steel	Flat Bar 1/4" x 1/4" x 72" Roll	Spiral	4 #		2.00
21.	1	Steel	Pipe 2" Sch. 40 x 4" lg.	Nozzle	2 #		1.00
22.	1	Steel	Elbow 1-1/2" F. P. S. 90°	Elbow	1 #		2.00
23.	1	Steel	Coupling 1/2" 3000#	Coup.	1 #		1.00
24.	1	Steel	Welding Neck Flange 2" 150# R. F.	Flange	6 #		5.00
25.	1	Steel	Welding Neck Flange 1-1/2" 150# R. F.	Flange	44 #		5.00
26.	1	Steel	Flange 12" 150# Slip On R. F.	Flange	55 #		10.00
27.	1	Steel	Pipe 1-1/2" x 6"	Nozzle	1 #		1.00
28.	28	Steel	Bolts & Nuts 3/8" x 5-1/2"	B & N	25 #		24.00
29.	1	Steel	Pipe 1-1/2" x 32" 9"	Legs	57 #		6.00
30.	4	Steel	Couplings 1-1/2" 3000#	Coup.	4 #		6.00
31.	1	Steel	Angle 4" x 4" x 1/4" x 24"	Foot pads	14 #		2.00
32.	2	Asbestos	Gasket 1/8" x 27-1/4" O.D. x 24" I.D.	Gasket	1 #		9.00
33.	1	316 S. S.	Tube 1/2" x 18 ga. wall x 35" lg.	Tube	1 #		5.00
			Form Heads Stainless $90.00 - Steel $21.00				111.00
			Total		1140 #		824.00

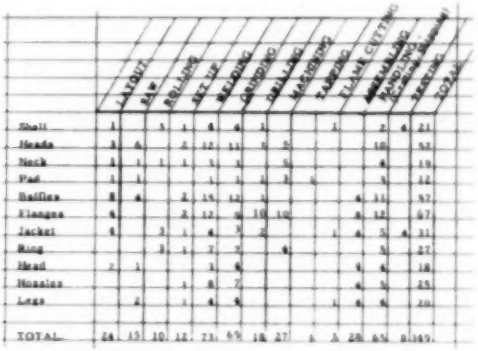


Fig. 3. Bill of materials for 24-in. diam. vessel.

In addition to material costs one needs cost factors on labor. These costs vary with each shop, depending on its particular characteristics. A few light sheet-metal shops and machine shops in the normal industrial areas of the United States operate for $4.00/hr. A considerable number of medium-weight metal-fabricating shops operate in the range of $5.00/hr., whereas many of the heavy shops have considerably higher rates.

Actual Cost Calculation of Small Pressure Vessel

Figure 2 shows cross-sectional views of a small 24-in., 40-gal., working capacity stainless steel vessel. It is designed and manufactured in accordance with A.S.M.E. Code for unfired pressure vessels, for 150 lb./sq.in. working pressure for the shell, and 100 lb./sq.in. gauge working pressure on the jacket, and is made of Type 316 stainless steel.

Figure 3 shows the cost of materials and labor, together with other costs, which may be summarized as follows:

Materials	$ 824.00
Labor—349 hr. @ $4.50/hr. (cost)	1570.50
Drawing & design	200.00
Inspection & code stamping	35.00
Freight	30.00
15% markup	400.00
Total	$3060.00

***Note:* 15% markup is not all profit; it includes an allowance for error and a profit before taxes of about 8%.)**

One of the relatively inexpensive types of processing equipment would be ordinary steel storage tanks. These are currently available in some markets at the following prices:

Capacity gal.	Dimensions—ft. diam.—length	Weight lb.	Price $
500	4	5½	700	90.00
1000	4	11	1200	145.00
2500	5½	15	2300	265.00
5000	7	18	5000	525.00

It is relatively easy for anyone to estimate material, but relatively impossible for anyone, even those skilled in the field, to estimate labor accurately. As a consequence and partly because everyone likes a rule of thumb, it is not unreasonable to seek some type of multiplying factor on material cost to give a selling price. Sometimes this is expressed in cents per pound rather than in a multiplying factor on the cost of materials themselves. A choice can be made since they both reduce to the same thing if done accurately.

One satisfactory rule of thumb for a well-designed, moderately complicated type of chemical equipment is that the selling price should be roughly three times the basic material, plus one and one-half times those items which are of large dollar value and which are purchased substantially finished from others, for instance, all the tank components times three, plus one and one-half, times agitator drive, motor, etc.

The same type of reasoning follows with condensers where the condenser tubing is a large part of the material cost, but is not so large a part of the actual fabricating labor. Here one may use three times the material, exclusive of tubing, plus one and one-half times tubing.

Actually, chemical plant equipment generally varies from one and one-half times total material to five times. Plain, heavy stainless steel tanks, welded only, without grinding or polishing of welds, etc. are not worth more than one and one-half times the basic material. Most equipment will run in the neighborhood of two and one-half to three times the basic material, whereas some items which are difficult to fabricate and must be polished, etc., will run higher.

As stated previously, if one wishes to convert this type of thinking into cents per pound, it may be done on straight fabricated equipment by adding one and one-half times the price of motors, drives, etc.

This presentation of elementary design and cost factors concerning unit prices of fabricated chemical engineering equipment should place an engineer in a position to evaluate bids and have some confidence in the prices and costs of the basic piece of fabricated equipment involved.

CAST ALLOY REFERENCE SHEET

N. S. MOTT, Chief Chemist Metallurgist

The Cooper Alloy Foundry Co., Hillside, N. J.

ALLOY: CORROSION AND GALLING-RESISTANT 19-10-3-2-3 CHROMIUM-NICKEL-MOLYBDENUM-COPPER-SILICON HARDENABLE ALLOY.

APPLICATIONS AND REMARKS: This alloy, developed primarily for nongalling and corrosion-resisting valve discs, finds usage in place of types 304 or 316 in applications where galling or erosion conditions exist along with corrosion. Resistance of V2B in the hardened condition to sulfuric, hydrochloric and phosphoric acids and their salts, exceeds that of all precipitation hardenable stainless alloys—even that of Type 316. In nitric acid it is also superior to the hardenable grades, but not the equal of 304 or 316 types, having resistance to all but the higher concentrations at boiling temperatures. V2B does not overage and lose its hardness at temperatures up to 1400° F. Its high hardness and strength, coupled with its excellent resistance to corrosives, plus its erosion-resisting and nongalling characteristics, suggest many applications such as: valve discs, plug cocks, wearing rings, poppets, conveyor links, rollers, gear blanks and other parts requiring both wear and corrosion resistance.

DESIGNATION: Type V2B *

MACHINABILITY: V2B is readily machinable in the quench-annealed state approaching the free-machining grades in characteristics.

HEAT TREATMENT: V2B should be water quenched from 2000° F. to put carbides and hardening constituents into solution. Following this the alloy may be hardened by holding at 925° F. for 8 hr. followed by furnace cooling. This treatment produces no distortion and only a light heat tinting discoloration which may be removed by a dilute nitric hydrofluoric acid pickle if necessary.

WELDABILITY: In the quench-annealed condition the alloy is readily weldable, using special V2B welding rods, by means of the shielded-argon arc technique.

BALANCED CHEMICAL COMPOSITION RANGE, PER CENT

Carbon	<0.07	Manganese	0.50 to 0.75
Chromium	19.0 to 19.50	Copper	2.0 to 2.25
Nickel	9.75 to 10.25	Molybdenum	3.0 to 3.50
Silicon	2.75 to 3.25	Beryllium	0.10 to 0.20

HARDNESS AND PROPERTIES OF V2B

	Brinell
Hardness:	
As-Cast	302
Quench Annealed	269
Annealed and Hardened	363
Mechanical Properties:	
Quench Annealed and Hardened	
Tensile Strength	151,600 psi
Yield Strength	122,400 psi
Elongation	3 pct
Reduction of Area	2 pct

HIGH TEMPERATURE CHARACTERISTICS

Hardness After 50 Hr. At Temperature

Temperature, Deg F	Bhn
Original	340
800° F.	340
900	340
1000	340
1100	302
1200	332
1400	351

CORROSION RESISTANCE OF V2B IN VARIOUS MEDIA

H_2SO_4

At	80° F.
50 per cent	0.00010
65	0.00001
78	0.00008

At	176° F.
10 per cent	0.00167
20	0.01170
30	0.02510
40	0.05000
50	0.5680
65	0.01790
78	0.00041
95	0.00005

Boiling	
½ per cent	0.00194
1	0.00233
2	0.00516
5	0.01800
10	0.03030
20	0.10400
30	0.29400
30	1.10000

HCl

At	80° F.
5 per cent	0.00100
10	0.02720
20	0.05980
37	0.11800

At	176° F.
¼ per cent	0.00010
½	0.00014
1	0.00192
2	0.00950

Boiling	
¼ per cent	0.00234
½	0.00363
1	0.01820

HNO_3

At	80° F.
65 per cent	0.00000

At	176° F.
50 per cent	0.00064
65	0.00095

Boiling	
5 per cent	0.00006
20	0.00044
30	0.00532
40	0.00950
50	0.00800
65	0.01200

Mixed Acids

HNO_3 H_2SO_4

At	80° F.
80-20	0.00006
60-40	0.00003
20-80	0.00004
20-60	0.00004

Boiling	
50-50	0.00705

H_3PO_4

At	176° F.
85 per cent	0.00000

Boiling	
20 per cent	0.00050
85	0.09430

CH_3COOH

Boiling	
100 per cent	0.00012

$Ca(ClO)_2$

At	80° F.
Sat.	0.00061

HF

At	80° F
10 per cent	0.17400
20	0.22100
48	0.02140
60	0.00811

NaOH

Boiling	
50 per cent	0.00134

RATINGS:

Excellent	< .00035
Good	.00035-.0035
Fair	.00335-.01
Poor	.01-.035
Not resistant	> .035

Recorded in inches penetration per month for a typical composition in the hardened condition.

No. 34

* Patented by Cooper Alloy.

By John Mellecker

Springfield, Mass.: Spring, 1954—New England in spring WAS beautiful. . . . Registration surpassed expectations by totaling 588. . . . Meeting rooms filled to standing room only. . . . Attentive audiences heard 22 papers and a panel discussion on subjects, ranging from a census of chemical engineering scale-up practices to how to make one's self effective in the give-and-take with the men in the plant.

PROCESS DESIGN received practical attention through W. W. Kraft's (Lummus Co.) symposium. Perhaps one of the most novel actions taken with regard to the preparation of a paper for an A.I.Ch.E. meeting was the census of what is regarded as good scale-up practice, undertaken by L. Michel, R. D. Beattie, and T. H. Goodgame of Godfrey L. Cabot, Inc. After accepting the responsibility for a paper "Extrapolation Limits for Process Equipment," they decided their contribution would be enhanced if they could include the experience of others. So they mailed questionnaires to 250 Active members of the Institute who are known to be actively engaged in process design. A reply was received from 40%, and the tabulation of results became the basis for the paper. Equipment items studied were plate and frame filters, rotary filters, centrifugal pumps, reciprocating compressors, screw conveyors, hammer mills, shell and tube heat exchangers (liquid-liquid), spray condensers, plate columns, packed columns, cooling towers, and cyclones.

IN THE BATCH VS. CONTINUOUS portion of the process design symposium, author A. Klinkenberg (Royal Dutch Shell) sent his message through the able presentation of C. O. Hurd (Shell Development Co.). It contained the following interesting generalizations: Batch processes need less equipment than continuous . . . are less costly to install, are favored for small units and, for new processes where the payout is uncertain. . . . The continuous process is more difficult to control manually; hence it is made automatic at increased capital cost, but at considerable saving in labor. . . . If the batch process is made fully automatic, its control may well become more complicated than that for the continuous unit. . . . The batch process is more flexible, but does not lend itself as well to heat economy by heat exchange. . . . Generally, continuous reactors have to be larger than batch, but care must be taken to provide additional capacity in the latter to make up for filling and emptying off-time.

A.I.Ch.E. PRESIDENT KIRKBRIDE has this to say about the meeting—"It was, to me, a typical national meeting. . . . Attendance was gratifying, and this in itself is a tribute to the program and vitality of the Institute. . . . However, it is not the attendance figures which proved the meeting to my mind. . . . The important thing was the wholehearted support of the local group and the creation of a technical program well adapted to the needs of the area. . . . This is what we have been striving for in our National meetings, since their beginning. . . . The plant trips, the banquet, the luncheon, and the symposia were all carefully planned to maintain a maximum interest in particular phases of our professional problems. . . . It was, in every sense of the word, a successful meeting."

THE OFT-CONSIDERED but sometimes-forgotten spectre of trace contaminant effect on the modern continuous process was brought out into the open by B. J. Mayland, R. M. Reed, and N. C. Updegraff of the Girdler Co. Their paper covered an experience with ammonia plants. They pointed out that a thorough analysis of presence of trace-factors vs. their capabilities of corroding, eroding, poisoning (as in the case of a catalyst), or accumulating physi-

Top to bottom:
Sunday afternoon panel scene.
Flowers for the ladies.
Technical session.
Press room.
General scene of meeting.
Kirkbride & Reese flank banquet speaker Secord.

Authors (l. to r.) Process Design Symposium: N. C. Updegraff, C. O. Hurd, W. W. Kraft (Chm.), L. P. Michel, J. R. Fair, Jr.; C. G. Kirkbride; A. S. Foss.

Arthur Secord (banquet speaker); H. L. Shulman; F. E. Reese (Arrangements co-chm.); D. B. Brunton, Mayor of Springfield.

W. W. Kraft; N. A. J. Platzer; Luncheon head table: F. R. Fisher, J. Magee (speaker), C. G. Kirkbride.

G. A. Latinen; W. I. McNeill, D. E. Pierce, M. T. Carpenter of Cost Controls Symposium; E. Perry (Chm. Gen. Tech. Session and Arrangements Co-chm.).

C. O. Hurd; C. C. Winding (Chm. Symposium Polymeric Materials); N. Nickolaus; W. S. Dodds.

N. C. Updegraff; J. R. Fair; F. M. Tiller; C. G. Kirkbride welcoming D. B. Brunton, Mayor of Springfield.

E. E. Lindsey (Chm. Gen. Tech. Session;) J. A. May; E. B. Fitch (Technical Program Chm.); E. E. Lindsey.

Unidentified questioner at Sunday afternoon session; W. E. Stevens; Sunday panel: A. V. Flint, J. K. Hayes (Chm.), G. J. Hutzler.

cally, can prevent many a start-up and operating difficulty.

CRACKING UNITS can be designed with greater convenience, as the result of information made available through the efforts of J. R. Fair of Humble Oil Co. and University of Texas, and H. F. Rase of the University of Texas. This design information is broadly applicable to petrochemical operations and should be of major value to chemical engineers contemplating entry, for their firms, into processing involving use of these raw materials. The most recent published work on this subject appeared in C.E.P. in the March, 1947, issue by H. C. Schutt of Stone & Webster Corp. We are advised that the new paper amends the earlier one. Early publication in C.E.P. is anticipated.

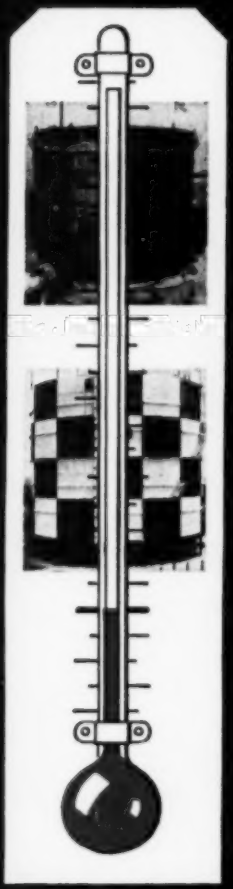
GETTING ALONG WITH THE MEN IN THE PLANT should be easier as a result of banquet-speaker Arthur Secord's five rules. Secord, a professor at Brooklyn College, is almost an evangelist on the subject and entertains while driving home a very worth-while message. Here is the gist of his five rules: (1) When addressing one of the men in the plant, be sure to speak *his* language. In other words, one should put himself in the man's position and try to talk about matters as they appear to him, (2) When criticizing his work, deal with only one critical point per meeting. If one waits until he has a long list of grievances, the major effect will be an impression of the critic, rather than the job operations which need rectification, (3) When correcting the man's job performance, try to demonstrate how the job should be done, selecting preferably some means for graphically getting the idea across that will remain indelibly on the man's mind from that moment on, (4) Never lead into a criticism with words of praise, unless one is willing to risk conditioning the man to a feeling from that moment on that praise may be only a prelude to "something else," (5) Never confuse pay with praise! In other words never praise a man in terms of a 3 cent/hr. raise, as he will almost surely resent not receiving the 5 cents he knows he's really worth.

WHAT A CHEMICAL ENGINEER SHOULD KNOW ABOUT COSTS might be termed the subject of the symposium organized and co-chairmaned by D. A. Dahlstrom (Eimco Corp.) and F. R. Fisher (Sinclair Research). Hints for selecting a plant-construction contractor, then giving him the kind of cooperation he needs, were covered by R. D. DeSimone (Construction Consult.)

A METHOD FOR CONTROLLING COSTS OF PRODUCTION was pre-

(*Continued on page* 38)

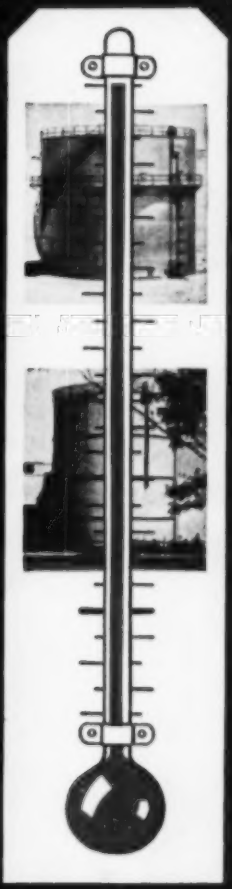
from the **ARCTIC** to the **TROPICS**



more than

130

WIGGINS GASHOLDERS have eliminated operating costs for users of chemical process and industrial gases



This 100% dry seal gasholder (no water, no tar, no grease) has proved itself under every condition of climate and temperature. Because of the seal and the simple operating mechanism, operating costs have been entirely eliminated. Comparison of maintenance expense by owners of Wiggins gasholders also shows remarkable savings. Companies who have converted old-type gasholders to the Wiggins advantages have been able to enjoy similar savings. Write for information.

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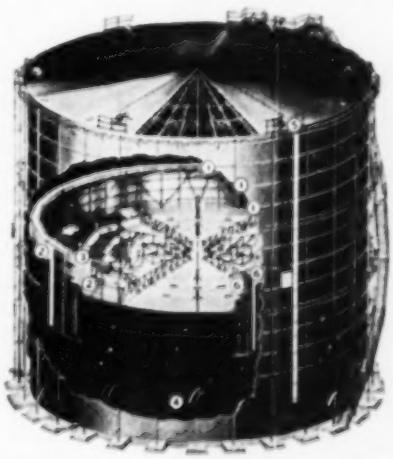
3. Gas-tight frictionless seal not affected by weather.
4. Piston rests on bottom when empty—less than ½ of 1% dead space for purging.
5. Leveling device—independent of side wall—keeps piston level.
6. Fenders prevent all tension in seal.



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W. C. Morin, J. W. Getz, S. E. Pritchard, E. E. Mohr, D. Williams and H. W. Koopman; A. I. Lockhart, Jr., S. Ricklin, Mrs. A. I. Lockhart, F. P. Klosek, B. J. Cottrell and J. H. Ankeney.

Pres. C. G. Kirkbride and Vice-Pres. B. F. Dodge; W. E. McWhirter, E. B. Fitch (Tech. Program Chm.) and A. S. Brunjes; J. M. Weiss.

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sented by the "team" of D. E. Pierce (Diamond Alkali) and W. I. McNeill (management consultant). Their method is based on the system of establishing process centers, which are broken down into two types—direct production operations and auxiliary service functions.

USE OF STATISTICS AND CONTROLLING RESEARCH COSTS were covered in separate papers by L. A. Seder (Quality Control Consultant) and M. T. Carpenter (Standard Oil Co.), respectively. As the science of statistics is being applied widely throughout process plant operation, as well as process development, market development, and so on, it was not surprising to observe the reasonable methods for its use in connection with the analysis of cost data by Seder. Employment of common sense in letting the research director propose a realistic analysis of desirable research projects was offered by Carpenter in lieu of formulas for determining how much it is wise to spend on research.

PLASTICS FOR CHEMICAL ENGINEERING CONSTRUCTION was given a thorough going-over by a team of authors from principal producing companies: B. M. G. Zwicker on rubber (B. F. Goodrich Chemical Co.) . . . R. J. Schatz and S. H. Rider on thermosetting resins (Monsanto) . . . R. B. Seymour on vinyls (Atlas Mineral Products Co.) . . . J. J. Ondrejcin on polyethylene, fluororesins, acrylics and cellulosics (DuPont). According to the mass of physical and chemical properties data now available, it would appear to be a detailed job to select the optimum plastic for a new chemical engineering application—especially considering the variety of plasticizers and copolymers that are available. . . .

CONTINUOUS PRESSURE FILTRATION was one of the subjects covered in Eli Perry's (Monsanto) general technical session. . . . The subject of continuous pressure filtration has a definite and increasing application with (1) high vapor pressure slurries, (2) high viscosity liquids or very fine solids, (3) where the usual labor cost advantage inherent in a continuous unit is one of the desired features, (4) where waste or by-product gases are present to enable collection under pressure, and (5) for filtration of unstable liquids that can crystallize under vacuum conditions . . . according to N. Nickolaus and D. A. Dahlstrom (Eimco Corp.).

HYDRAULIC GRADIENTS, which are heads that cause liquid to flow across distillation bubble trays, often cause uneven bubbling in large diameter trays used in the chemical industry. . . .

(*Continued on page* 61)

WHEN TEMPERATURE IS A PRIME FACTOR

Tube Selection Cannot Be Reduced to a Formula — Even a Complicated One

Many variables are involved in the selection of the optimum tubing for a specific high temperature application. If the tubing is also to operate under high stress, perhaps the most important variable to be considered is mechanical strength.

In general, the mechanical strength of a steel decreases as the temperature increases. Some steels, however, retain more of their strength at elevated temperatures than others. For instance, at 300F, the ultimate strength of both carbon steel and B&W Croloy 18-8 (Type 304) is about 70,000 psi. At 1200F, however, carbon steel is about 12,000 psi while Croloy 18-8 is about 44,000 psi.

To evaluate the characteristics of metals operating under stress at high temperatures and over long periods of time, B&W has performed stress rupture tests and creep tests on a great number of tubing steels.* The results of these tests help engineers to determine the proper tube to be used in specific applications.

Other factors beside mechanical strength, however, must be considered in choosing the optimum tubing for a specific high temperature application. Some of these factors are—oxidation resistance, tube size, tube cost, flow rates, and rates of conductivity and expansion.

It takes an expert to specify the right tubing for any particular application, and there is no substitute for the kind of experience with these problems you'll find at B&W.

To get the most benefit from B&W's long experience in matching tubes to jobs, call on Mr. Tubes, your nearby B&W Tube Representative. He can help you make the best choice.

Data shown in
TDC 102 Creep Stress Data on B&W Croloys

TDC 153 Stress Rupture Data on B&W Croloys available free on request.

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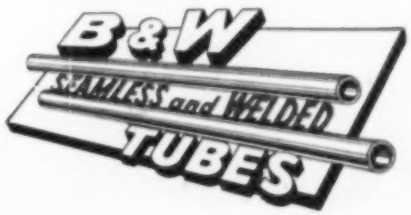


TA-4023 (P)

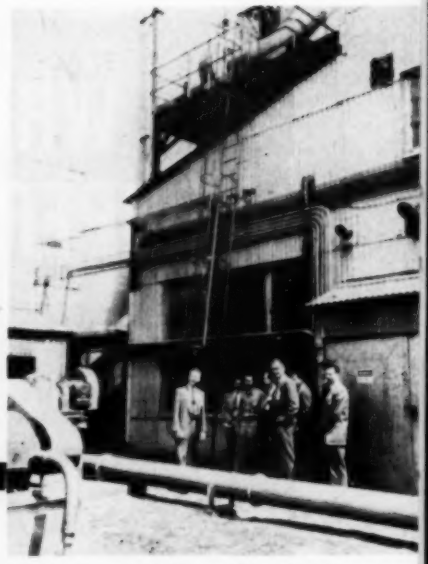
PLANT TOUR

What it is like to take an A.I.Ch.E. plant tour as part of the program offered during a National Meeting is shown in the accompanying pictures. Even if one has experienced such a tour, taking an arm-chair version may be enlightening. Showing a typical group going through the Monsanto Plastics Division plant at Springfield, Mass.

Photos by Lee Child, Monsanto Staff Photographer.

In the bus en route to the plant, Monsanto host V. E. Gregory explains what the program will be and collects lighters and matches.

Approaching the guard-house for checking-in and assignment of guides.

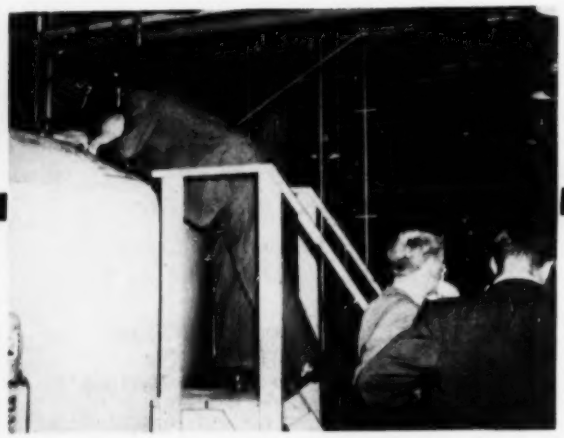


Outside the wood-flour sifting department where the filler-material for phenolic molding powders is made ready for blending.

Approaching the formaldehyde plant, which produces a vital raw material for the Resinox (phenol-formaldehyde polymer) plant just seen.

Looking through a porthole down into upper sections of resin kettles are exposed and connected to the maze of piping.

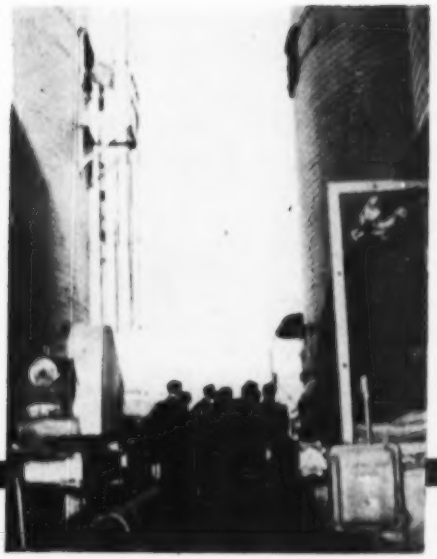
Examining the automatic control panel of the formaldehyde plant, with assistance from Harold Knapp, Monsanto foreman, Formaldehyde Dept. (center).



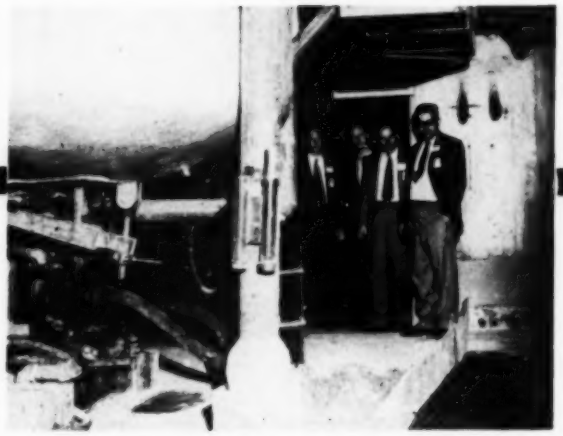
Looking through a port-hole down into the catalytic reaction chamber in which the formaldehyde is produced.

* *Trade Name.*

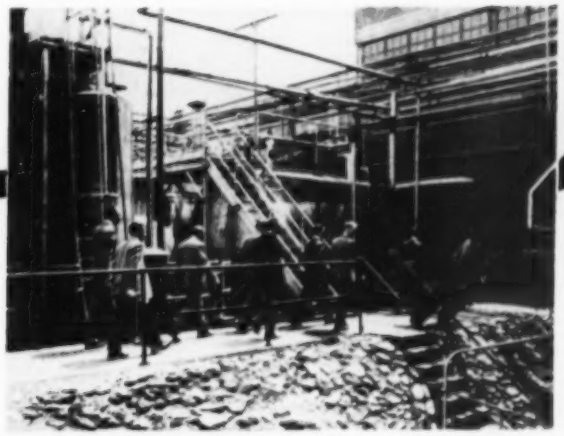
Roland Dunlop, Monsanto asst. operating supervisor, pointing out details of the wood-pulverizing unit.



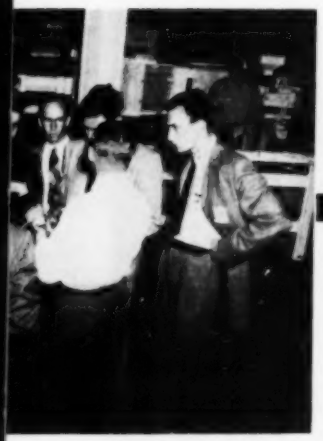
Walking out between the wood flour storage silos, en route to the Resinox ® plant.



At the bottom of a large phenolic resin (Resinox) kettle reactor where the partially polymerized and hot, viscous mass is cooling on the floor at the right. After hardening it is broken up with air hammers.



Passing the bulk liquid raw materials storage tanks at the entrance to the Resinox plant.



In the injection molding (production testing) dept. of Lustrex® (styrene), examining the crystal-clear samples which were opaque powder earlier.

Observing the sheeting of a cake of Nitron® (cellulose nitrate), which moves back and forth under the stationary knife blade.

Finale. With aching feet but happy countenances, (l. to r.) J. W. Getz (Westvaco), H. W. Koopman, Jr. (Westvaco), F. W. Velguth (Corn Products Refining), J. A. Mraz (National Carbon), W. E. Stanley, Jr. (Standard Oil), J. L. Galt (General Electric), C. Fishkin (Monsanto Guide) and A. W. Helwig (Ethyl Corp.).

New Triple Superphosphate Plant Opened by Davison Chemical Corp.

Two hundred thousand tons will be soon added to the current national annual output of 1,000,000 tons of triple superphosphate when the new $10,400,000 plant of The Davison Chemical Corp. located near Bartow, Fla., reaches its rated capacity. Demand, according to forecasts of the Department of Agriculture, is expected to reach 1,600,000 tons by the end of this year.

The Davison plant will operate continuously to process phosphate rock mined at the Davison properties in Bartow, about 325,000 net tons a year of rock being required. The rock is ground in three roller mills in closed circuit with "whizzer" separators and is then reacted, or treated, with sulfuric acid in a series of tanks equipped with agitators. Lower phosphate content rock than usual can be used in this process, according to Davison engineers.

The sulfuric acid plant at the site was designed by Monsanto Chemical Co. and has a rated capacity of 550 tons of 100% acid a day, which Monsanto claims makes it the largest contact process unit in operation. Heat developed in this process is used to power much of the equipment of the triple superphosphate plant.

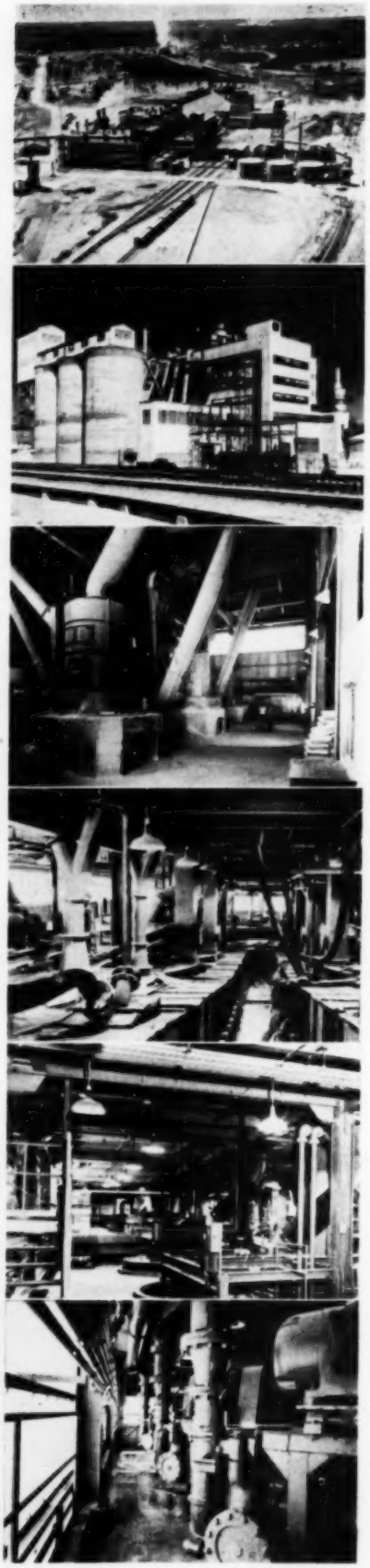
The phosphoric acid solution produced by the reaction with sulfuric acid has suspended in it a precipitate of gypsum, which will be used as fill in the mined areas. The slurry of phosphoric acid and gypsum is filtered on traveling pan-type filters which separate the gypsum from the slurry, and the resultant clear phosphoric acid is then pumped to evaporators for concentration. Three single-effect vacuum evaporators 15 ft. high and 6.5 ft. in diam. are used; they are lined with rubber and contain tubes constructed of Karbate for resistance to corrosion.

The concentrated phosphoric acid is mixed with more ground phosphate rock in a series of agitated reaction vessels and is then mixed with recirculated fine triple superphosphate and fed to an oil-fired, direct-heat, concurrent rotary drier. The finished triple superphosphate is screened to separate, or "scalp out," oversize and undersize particles, which are recycled into the process. The finished product undergoes a brief final curing before being shipped in both pulverized and granulated form.

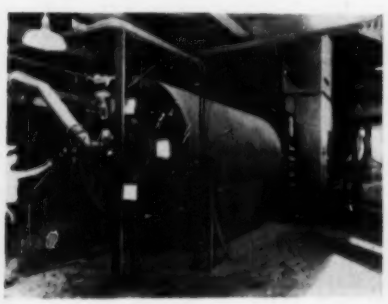
The plant was constructed by Consolidated Engineering Corp., the Dorr Co. being the architect-engineers, in the area of the largest known reserves of phosphate rock east of the Mississippi River. Nearly 80% of all the nation's triple superphosphate is produced in Florida.

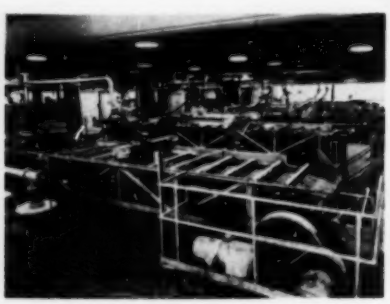
In 1930 the total production of triple superphosphate in the United States was 100,000 short tons produced in five plants. By 1951-52 production had increased to 765,358 tons in nine plants. Ordinary superphosphate had increased from 3,756,000 tons in 1930 to 9,595,255 tons in 1951-52.

(*More News on page* 44)



Reading clockwise: (1) airplane view of Davison Chemical Corp.'s new triple superphosphate plant showing the phosphoric acid manufacturing section on the left, the triple superphosphate manufacture and phosphate rock grinding section immediately in back of it, and the sulfuric acid plant on the right across the tracks; (2) the rock-grinding section with storage silos for rock at the left, the triple superphosphate production building at the right, and one of the dust scrubbers (with tower) at the far right; (3) three Raymond 66-in. roller mills; (4) phosphoric acid reaction train; (5) upper level of equipment shown in (4); (6) slurry-recirculating pumps used in conjunction with the phosphoric acid reaction train; (7) Giorgini traveling pan filters used for removing gypsum from phosphoric acid; (8) oil-fired rotary drier (combustion chamber is in foreground).





KNAPP TO PRODUCE PLASTIC EQUIPMENT

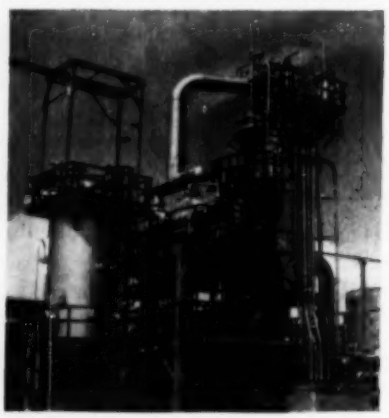
The production of large-scale chemical and process equipment from unplasticized polyvinyl chloride has been announced by Knapp Mills, Inc., producers of lead-clad steel and copper. In announcing these plans, Alfred P. Knapp, president of the company, said, "Our survey indicated that European engineers had had great success in the production of massive and complicated chemical equipment from plastics, some of it in service as long as fifteen years. Wherever permanently successful applications had been developed, it was observed that the material used was unplasticized polyvinyl chloride. . . . Our investigation revealed that the use of unplasticized polyvinyl chloride in American industries has had excellent results in many of the simpler applications. . . . There is no reason why the European success with plastics in the production of big equipment cannot be equalled here." The construction material decided upon by Knapp is Boltaron 6200 and 7200, distributed by H. N. Hartwell and Sons, Inc.

CHEMICAL MILLING OF METALS DEVELOPED

A new chemical milling process that precision-forms metal parts without the use of milling machinery has been developed by North American Aviation, Inc., in conjunction with Turco Products, Inc. In this etching process the metal to be removed is left exposed and the rest of the part is covered with a specially developed coating; then the entire part is submerged in a chemical solution which attacks the exposed surfaces evenly at a constant rate until the desired amount of metal has been etched away. The process is electronically controlled and according to its developers produces finished metal surfaces to accuracies of 0.002 in. Besides permitting the holding of close tolerances, the process is claimed to encourage advanced design not possible with conventional machine milling and to permit tapering, curving, and other intricate shaping.

Chem-Mill, as the process is called, has been confined to aluminum alloys, but its application to other metals is being developed.

HYDROFINING PROCESS LICENSED



A Hydrofining unit installed in the Fawley, England, refinery of Esso Petroleum Co., Ltd. The process, used to upgrade petroleum products and remove undesirable sulfur material from refinery intermediate oil products, is now available under license from Standard Oil Development Co. to other companies in the industry. Heretofore the process was restricted to affiliates of Standard Oil Co. (New Jersey).

HERCULES GETS AMMONIA PLANT FROM GOVERNMENT

Hercules Powder Co. has announced leasing with an option to buy the government-owned Missouri Ordnance Works, which it built for the Army Ordnance Department in 1941-1942. Originally consisting of five anhydrous ammonia lines, the plant now has three high-pressure lines using natural gas as a raw material and having an annual capacity of approximately 42,000 tons of ammonia. The price given was $3,625,000.

Because of its position as builder and first operator of the plant, Hercules had the option of taking over the plant from the Engineers Corps at the highest bid received by the government.

PUBLIC TO USE IDAHO REACTOR

Irradiation services from the Materials Testing Reactor at the National Reactor Testing Station in Idaho have been made available to the public, according to a recent announcement from the Atomic Energy Commission. The reactor is a high-intensity neutron source and produces isotopes of higher specific radioactivity than the Argonne, Brookhaven, and Oak Ridge reactors, which also offer such services. The prime purpose of the M.T.R. is to test materials that would be used in future reactor construction.

Requirements of the atomic energy program will take precedence over non-government experiments in all areas of the reactor. Security considerations require that all experiments requested by the public be operated by the contractor, Phillips Petroleum Co. of Idaho Falls.

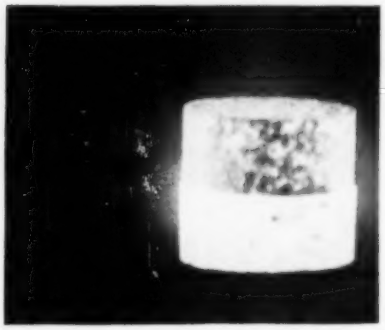
(Continued on page 46)

NEWS

(*Continued from page 44*)

NEW ISOTOPE MATERIAL SEPARATED BY A.E.C.

Cesium-137, the most important long-lived gamma-ray-emitting isotope found in spent reactor fuel, has for the first time been separated and compressed into pellets, according to an announcement by the Operations Division of Oak Ridge National Laboratory of the Atomic Energy Commission. The two pellets made so far, each about 1¼ in. in diam., a little more than ½ in. thick, and averaging a little more than 1 oz. in weight, will be used as a radiation source in a new teletherapy unit being prepared for cancer research in the Oak Ridge Institute of Nuclear Studies. The two pellets contain 1,540 curies of radioactivity, equivalent in radiation energy to more than 1 lb. of radium, which would cost over $1 million. The cost of cesium-137 has not been determined, but it is hoped that in volume production the price will be competitive with that of cobalt-60, which has similar applications.



Self-photograph of two cesium-137 pellets taken by the light of their own radioactivity during a 4-hour exposure. The pellets were prepared from dry powdered cesium chloride under a pressure of 20,000 lb./sq.in. After pressing, each pellet was placed in a stainless-steel jacket closed by silver soldering and then the jacketed pellet was in turn sealed in another stainless-steel jacket.

As a radiation source cesium-137 has several advantages over a cobalt source. Its half life of 37 years is over seven times that of cobalt-60, although it does not compare with radium's almost 1600 years. The gamma radiation energy of cesium-137 is 0.66 Mev., compared with 1.2 Mev. for cobalt-60, and therefore permits successful deep therapy with less shielding than cobalt requires. The energy of the two pellets combined is comparable to the peak energy given out by much more expensive million-volt X-ray machines. Two years of research was devoted to the cesium program, the work being carried out in a comparatively small pilot plant.

WYANDOTTE INAUGURATES GREAT LAKES SHUTTLE

Transportation of bulk chemicals via the Great Lakes between Wyandotte, Mich., and Chicago has been announced by Wyandotte Chemicals Corp., which will employ three converted ore freighters as floating warehouses. Each carrier will have a capacity of 6,000 tons of soda ash, 1,000 tons of caustic soda, and 500 tons of miscellaneous bulk chemicals.

Under a shuttle system one carrier will be loading at Wyandotte while another is towed by a tug to a reloading point south of Chicago and a third carrier is docked in Chicago to transfer cargoes to barges for shipment south over the Illinois waterway.

The three ore freighters are being converted to carriers by removal of boilers, machinery, and propellers, streamlining of the hulls, enlargement of the rudders, and provision of deck cranes for self-unloading. The carriers can be loaded directly from production and may act as a floating storage when immediate unloading is not desired. Use of the carriers evolved from the fact that river barges do not carry enough cargo to be economical, groups of barges are not feasible on the Great Lakes, and a large self-powered lake ship would necessitate large storage areas for transshipment at Chicago.

Movement of bulk chemicals through the Great Lakes and down the midwestern river system to consumers whose plants are on or near these waterways systems at a lower rate than by other means of transportation has been studied by Wyandotte for some time.

BREA CHEMICALS OPENS AMMONIA PLANT

The $13 million ammonia plant opened at Brea, Calif., recently by Brea Chemicals, Inc., a subsidiary of Union Oil Co., is expected to operate at full capacity some time in June, when it will produce 235 tons of ammonia daily. A storage capacity of 20 million gallons of aqua ammonia will permit the new plant to supply agricultural needs in the western United States, Mexico, and the sugar plantations of Hawaii.

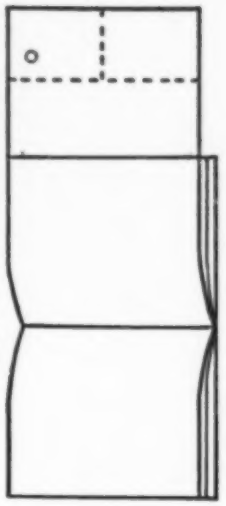
The Brea ammonia plant is the first major manufacturing operation of the company. Adjacent to the plant a carbon dioxide plant is under construction, and a $2½ million nitric acid and ammonium nitrate plant is planned. The ammonia plant is owned and is being built by The Amoniaco Corp. of Delaware and operated by Brea Chemicals under a long-term lease. Brea designed the installation, which was constructed by C. F. Braun & Co.

(*More News on page* 58)

for. your information

This C.E.P. information service is a convenient way to get the chemical engineering information you need on the new equipment, on advertised products, on the newly announced developments reported on these pags. A one post card inquiry designed to bring data quickly and easily. Circle the items of interest, sign your name, position, address, etc., and drop in the mail.

Just a moment is needed to learn how to use this insert. When looking through the front part of the magazine pull the folded portion of the insert out to the right, and the numbers on the post card are convenient for marking. THEN . . . .



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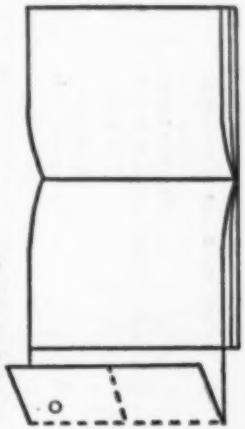

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PRODUCTS

IFC **Rotary Disc Contactor**
For liquid-liquid counter-current extraction.
Turbo-Mixer Div., General American Transportation Corp.

3R **Draver Feeders**
For dry powdered, granular or crystalline materials. Capacities from minute quantities up to thousands of pounds per hour.
B. F. Gump Co.

4L **Sintered Glass Filters**
Featuring filter plates and filter discs.
Ace Glass, Inc.

5A **Steam Traps**
Types for every process, power, heat application. Catalog.
W. H. Nicholson & Co.

6A **"Karbate" Pipe and Fittings**
Also hand tools developed for threading and serrating "Karbate" pipe. Heat exchangers and centrifugal pumps.
National Carbon Co.

8A **All-Iron Valves**
For ammonia and other hard-to-handle fluids.
Crane Co.

9A **Vacuum Filters**
Features high submergence (55%) stainless steel drum type filter equipped with compression rolls, string discharge and wash headers.
The Eimco Corp.

10L **Filters**
Any kind of filter paper, cloth, or screens, and any filter media can be used.
Sparkler Manufacturing Co.

11A **Pressure Controllers**
Designed to handle both positive and negative pressures, from high vacuum to pressures of up to 10,000 lb. Also liquid level controller pilots.
Black, Sivalls & Bryson, Inc.

12A **Celite Diatomite Powders**
Provide bulking action to industrial formulations.
Johns-Manville

13A **Processes, Plants and Apparatus**
Description of three new natural gas reforming plants.
The Girdler Company

14L **Design and Fabrication**
Features an 85 foot column to handle a key distillation step in a processing plant.
Badger Manufacturing Co.

15A **Recorder-Controller**
Universal instrument, equally adaptable to any process measurement—flow, temperature, pressure, liquid level.
The Foxboro Co.

16A **Haveg Construction Material**
Haveg, a plastic molded in the form of finished process equipment, available for many types of field fabrication.
Haveg Corp.

18A **Traveling Stacker**
Stacker discharges 1,088 foot center trunk line belt conveyor to either side. Rock is piled at a rate of 635 long tons/hr.
Stephens-Adamson Mfg. Co.

19A **Valves and Valve Lubricants**
Rockwell-Nordstrom lubricant-sealed valves and valve lubricants. Quarter-turn closing.
Rockwell Mfg. Co.

21A **Graphite Anodes**
Graphite anodes for the electrolytic industry in making chlorine and caustic soda for antiknock compounds.
Great Lakes Carbon Corp., Electrode Div.

22A **Glass Pipe, Coolers**
Pipe available in 1 in. to 6 in. I. D. Also fractionating columns, packed columns and cascade coolers.
Corning Glass Works

23A **Dryers**
Features experience in designing and building dryers.
Louisville Drying Machinery Unit, General American Transportation Corp.

24L **Ball Bearing Swivel Fittings**
Type "LPR" for low pressure service. Pressures to 1,000 lb./sq.in. and temperatures to 225° F. Sizes 1¼ in. to 4 in. For liquids, semi-solids, gases, steams, etc.
Emsco Manufacturing Co.

25A **Valves**
Solid, unfilled Teflon, in a wedge-ring arrangement, provides packing for Lapp Porcelain valves.
Lapp Insulator Co., Inc.

26A **Yorkmesh Demisters**
Features case study of problem caused by fine caustic spray from a scrubbing tower.
Otto H. York Co., Inc.

27A **Centrifugals**
Type HS universal centrifugal, capacities from laboratory sizes to 16,000 lb./hr. Type S continuous centrifugal, capacities from laboratory sizes to 48,000 lb./hr.
Baker Perkins, Inc.

28L **Teflon-Jacketed Gaskets**
For stainless steel, glass-lined steel and conical-flanged glass pipe. Also snap-on gaskets and adaptors.
United States Gasket Co.

29A **Fluid Phthalic Process**
Describes two phthalic anhydride plants currently under construction in Europe.
The M. W. Kellogg Co.

30A **Electrical Weighing System**
Measures batch ingredients automatically.
Minneapolis-Honeywell Regulator Co.

32L **Primers**
Through controlled polymerization, primer is indicated to make protective coatings last longer.
Carboline Co.

33A **Urea**
Foster Wheeler, exclusive licensor in the United States, is now designing and constructing two Pechiney urea plants with a combined capacity of 410 tons/day.
Foster Wheeler Corp.

34A **Micro-Feeder**
Standard models for feeding from 1.0 cc. to 800 cc./hr. and for maximum discharge pressures up to 2,000 lb./sq.in. gauge.
Proportioners, Inc., Division of B-I-F Industries, Inc.

Chemical Engineering Progress

Numbers followed by letters indicate advertisements, the number corresponding to the page carrying the ad. This is for ease in making an inquiry as you read the advertisements. Letters indicate position—L, left; R, right; T, top; B, bottom; A indicates a full page; IFC, IBC, and OBC are cover advertisements.

Be sure to give name, address, position, etc.

Remember, the numbers on the upper portion of the card bring you data on only the bulletins, equipment, services, and chemicals reported in these information insert pages. The lower portion of the card is for the advertised products, and is keyed not only to advertising pages, but also to the memory-tickling list under the heading Products.

274A **Durisite**
A mortar indicated to resist both acids and alkalis.
The U. S. Stoneware Co.

37A **Gasholders**
Description of all-weather gasholders.
Wiggins Gasholder Div., General American Transportation Corp.

39A **Tubular Products**
Seamless tubing; welded stainless steel tubing, and welded carbon steel tubing.
The Babcock & Wilcox Co., Tubular Products Div.

43A **Double Drum Dryers**
Dryers, evaporators, kettles, and equipment for processing chemicals and foods.
Blaw-Knox Co., Buflovak Equipment Div.

44L **Pumps and Compressors**
Built-in valve automatically prevents reverse flow through compressor and also dampens pipe line pulsations.
Pennsylvania Pump & Compressor Co.

45A **Control of Process Heat**
Heat transfer medium maintains temperatures within a fraction of a degree. Used as a vapor heating medium in a closed system.
The Dow Chemical Co.

46L **Drying Research**
Dryers, with each variable adjusted as desired.
C. G. Sargent's Sons Corp.

(Continued on back of this insert)

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Advertisers' Products

IFC	3R	4L	5A	6A	8A	9A	10L	11A
12A	13A	14L	15A	16A	18A	19A	21A	22A
23A	24L	25A	26A	27A	28L	29A	30A	32L
33A	34A	274A	37A	39A	43A	44L	45A	46L
47R	48A	57A	58L	59R	60L	61R	62L	63R
64L	65A	66L	67R	68L	69R	70L	71R	73A
74A	75B	76L	76TR	76BR	77T	77B	78T	78B
79R	80L	81T	81B	82T	82BL	82B	83TL	83BL
83R	85T	85B	87R	88T	88B	89B	IBC	OBC

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33A	34A	274A	37A	39A	43A	44L	45A	46L
47R	48A	57A	58L	59R	60L	61R	62L	63R
64L	65A	66L	67R	68L	69R	70L	71R	73A
74A	75B	76L	76TR	76BR	77T	77B	78T	78B
79R	80L	81T	81B	82T	82BL	82B	83TL	83BL
83R	85T	85B	87R	88T	88B	89B	IBC	OBC

Chemical Engineering Progress Data Service

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Company .....

Address .....

City .....Zone .....State .....

☐ I want a subscription. Bill me $6.00 for a year.

June, 1954

PRODUCTS (*Continued*)

47R **Centrifugal Pumps**
Primarily engineered for the application of the mechanical shaft seal. Also available for use with conventional packing. Bulletin.
Pacific Pumps, Inc.

48A **Valves**
Single-seated valve controls pressure differentials as high as 3,600 lb./sq.in. Sizes: 1 in. to 8 in.
Hammel-Dahl Co.

57A **Twin Shell Blender**
Complete mixing and blending process. Dust control system draws dust through pipes to an air-filtering plant outside the main building.
The Patterson-Kelley Co., Inc.

58L **Silicone Defoamers**
Indicated to increase processing equipment capacity by eliminating space-wasting foam.
Dow Corning Corp.

59R **Tantalum**
Acid-proof tantalum equipment for chemical operations. Booklet.
Fansteel Metallurgical Corp.

60L **Florex for Adsorption**
Used in the adsorptive refining, decolorization, clarification and neutralization of mineral, vegetable, and animal oils, fats and waxes.
Floridin Company

61R **Proportioning Pumps**
Capacities from 0.10 to 24 gal./hr./feed, 1, 2, 3 and 4 feed units are available.
Hills-McCanna Co.

62L **Chlorination**
Slime control equipment designed for any need.
Wallace & Tiernan

63R **Y Valves**
Features renewable disc ring and Teflon-to-alloy seating. Coversion to 90 degree angle valve by rotation of body halves.
The Duriron Co., Inc.

64L **Filter Papers**
Manufacture of filter papers for laboratory and industry. Booklet.
The Eaton-Dikeman Co.

65A **Stainless Components**
Stainless steel valves, fittings and accessories.
The Cooper Alloy Foundry Co.

66L **Air Conditioning**
Cooling and heating functions are made completely separate from adding or taking away moisture.
Niagara Blower Co.

67R **Metallic Filter Cloth**
Available in a variety of weaves in all malleable metals. Catalog.
Newark Wire Cloth Co.

68L **Tank and Duct Material**
Resistant to temperatures of over 200°.
The Chemical Corp.

69R **Stainless Steel Vapor Condensers**
Standardized vapor condensers. Literature.
Doyle & Roth Mfg. Co., Inc.

70L **Grinding Mills**
Conical, tube, tricone, rod, batch, and cylindrical mills.
Hardinge Co., Inc.

71R **Continuous Combined Evaporator-Strippers**
Designed to separate the volatile and non-volatile components of a liquid mixture continuously. Sizes handle from 25 to 1,000 gal./hr.
Artisan Metal Products, Inc.

73A **Ratographic Miniature Indicators**
Fits panel space 2⅜ in. x 5⅜ in., with 5¼ in. long, readable scale in keeping with ½% accuracy.
Fischer & Porter Co.

74A **Thermal Insulation**
Line of insulations for service temperature from minus 400° F. to plus 3,000° F.
Johns-Manville

75B **Condensers**
Features 9,000 sq. ft. condenser for utility plant, and 3,500 sq. ft. condenser serving the turbine drive of the main air compressor in a refinery.
Condenser Service & Engineering Co., Inc.

76TR **Heat Transfer Equipment**
Heat exchangers, towers, pressure vessels, storage tanks, and plate fabrication.
Downingtown Iron Works, Inc.

76BR **Water Filters**
Porous stainless steel elements, 0.2 to 1,000 gal./min. service.
Micro Metallic Corp.

76L **Motors**
Any rev./min. by dial control. ¼ to 50 hp., 2 to 10,000 rev./min.
U. S. Electrical Motors, Inc.

77T **Telephone Systems**
Sound powered handsets may be used for either permanent or portable communication.
United States Instrument Corp.

77B **Spraco Nozzles**
Full cone, flat spray and hollow cone spray nozzles. Catalog.
Spray Engineering Co.

78T **Bubble Caps**
Bulletin 21 lists 200 styles. Special caps designed.
The Pressed Steel Co.

78B **Meters**
Xacto meters to measure liquids accurately and dependably.
Bowser, Inc.

79R **Heat Exchangers**
Also special equipment, pilot plant units and plant modernization programs.
Davis Engineering Corp.

80L **Vitreous Silica Tubing**
Available from stock in transparent, glazed, sand surface and satin surface types.
The Thermal Syndicate, Ltd.

81T **Distilled Water**
Unit attaches to water faucet. Several models with varying capacities.
Enley Products, Inc.

PRODUCTS (*Continued*)

81B **Universal Joints**
Diameters ½ in. to 4 in.—bores ¼ in. to 2 in.—lengths 2 in. to 105⅝ in. Also flexible couplings, variable speed pulleys and transmissions.
Lovejoy Flexible Coupling Co.

82T **Pumps**
For highly abrasive mixtures, corrosive liquids, hot solutions or heavy slurries. Horizontal and vertical shaft types in complete range of sizes.
Nagle Pumps, Inc.

82BL **Shielding Windows**
Zinc bromide for viewing windows. AEC specifications.
Michigan Chemical Corp.

82B **Hydrostatic Gauges**
For pressure, vacuum, draft depth and absolute, barometric, and differential pressure. Bulletins.
Uehling Instrument Co.

83TL **Stainless Steel Products**
Pipe, pails, pumps, rivets, scour cloths, sight flow glasses, taper pins, tubing, tubing fittings, ware, etc.
Schnitzer Alloy Products Co.

83BL **Unit Spray Dryer**
Stainless steel construction, light weight, small area installation.
Foster D. Snell, Inc.

83R **Color Comparators**
For determinations of pH, chlorine, phosphate, as well as complete water analysis.
W. A. Taylor and Co.

85T **Filtering, Mixing, and Storing**
Filter, mixer and storage, and mixing tanks. Complete range of sizes and capacities.
Alsop Engineering Corp.

85B **Skin Barrier Cream**
Indicated to offer skin protection against irritants and sensitizing agents encountered in industry.
Ayerst Laboratories

87R **Books for Chemical Engineers**
New titles include "Modern Electroplating," "Organic Coating Technology," "A French-English Dictionary for Chemists," and "Statistical Analysis in Chemistry and the Chemical Industry."
John Wiley & Sons, Inc.

88T **Proportioning Pumps**
7,500, 15,000 or 30,000 lb./sq.in. working pressure by the interchange of piston and cylinder assemblies.
American Instrument Co., Inc.

88B **Furane Cement**
A mortar for corrosion-resistant masonry.
Delrac Corp.

89B **Evactors**
Illustration shows two 4-stage evactors in pharmaceuticals plant. Also jet mixers, jet heaters, etc.
Croll-Reynolds Co., Inc.

IBC **Process Equipment Fabrication**
Pressure vessel design and fabrication.
The Vulcan Copper & Supply Co.

OBC **Mixers**
Supplied in the exact power-speed-torque combination needed.
Mixing Equipment Co., Inc.

CHEMICALS

1 **Foamed Plastic.** Nopco Chemical Co. Lockfoam is described in 28-page booklet. Included are charts, graphs, photos. Applications such as electronic devices, packaging, thermal insulation are suggested.

2 **Neoprene.** DuPont Co. Neoprene Notebook No. 58, Part V, treats the subject of load-carrying capacity of rubber, neoprene putty as used to seal construction joints in hollow concrete foundations, & other pertinent data.

3 **Silicone Fluid.** Said to be compatible with organic materials is silicone fluid from Dow Corning Corp. Useful temperature range limited to −70° to 300° F. Alcohol solution said to have high order of water repellency, stability, oxidation resistance. Not hindered by emulsifiers.

4 **Zeolite Softener.** ZEO-FLO softeners designed for small & medium size plants. Easily installed & operated. Operation, design, other information available in bulletin from Hening & Co., Inc.

5 **Polyester Resin.** Hetron, a corrosion-resistant polyester resin said to have light stability combined with good fire resistance. Used in combination with glass fiber for fabrication of tanks, duct work, etc. Shows no visible yellowing or loss of surface gloss after 500 hr. in weatherometer. Hooker Electrochemical Co.

6 **Irradiated Polyethylene.** General Electric Co. Irrathene represents an advance in heat & chemical resistance over normal polyethylene with superior properties resulting from bombardment with high-energy radiation. Stability at 300 to 350° F. Offered experimentally in narrow film form.

7 **Aero Phthalic Anhydride.** A 24-page booklet from American Cyanamid Co. gives up-to-date description of properties & uses, chemistry, technical data, methods of handling sample & analysis, plus applications.

8 **Acrylates.** Available in pilot plant lots methoxyethyl & butoxyethyl acrylates from Rohm & Haas Co. Now can also be made available in commercial quantities. Monomers polymerize & copolymerize with usual peroxide-type catalysts in bulk solution, or emulsion methods. Polymers may be cured by exposure at room temperature for several weeks or at 100 to 150° for a few hours. Excellent adhesion to wood, glass, & metals. Little effect after prolonged immersion in toluene, hexane, acetone, or ethyl acetate.

9 **Pyridine.** New brochure on Pittsburgh Coke & Chemical Co. pyridine describes uses & properties. Also company's new recovery service which enable users to reduce pyridine costs by increasing economically feasible uses as well as increasing over-all availability of pyridine. Applications, specifications, solubility characteristics listed.

10 **Organic Acids.** Booklet on organic acids from Carbide and Carbon Chemicals Co. discusses in detail eight organic acids sold commercially. Sections on physical properties & specifications, uses in many industries, constant boiling mixtures, handling & storage procedures. Section devoted to test methods.

11 **Radioactive Carbon.** Tagged Versene, presently being synthesized & dispensed by Radioactive Pharmaceuticals division of Abbott Laboratories for research. Inherent stability permits following course of metals or trace compounds wherever study in fluid systems or solutions is required. Minimum shipments ¼ mc. (millicurie).

Supplied only to institutions or individuals with valid A.E.C. allocation. Activity 8 mc./g.

12 **Furan Chemicals.** Furfural family of commercial & semi-commercial products are discussed in 28-page booklet from Quaker Oats Co. Also lists furfural-derived chemicals available in commercial & experimental quantities. Appendix shows engineering drawing, describes handling & storage layouts, etc.

14 **Styrene-Butadiene Lattices.** Offered in five different copolymer ratios styrene-butadiene lattices from Koppers Co., Inc. Technical bulletin supplied detailed description of 15 different lattices available. Also discusses characteristics of color, solids content, mechanical stability, shelf life, odor & ability to dilute with water. Suggested uses listed with other information.

15 **Polyethoxy Amines & Calcium Acrylate.** Bulletin on series of Priminox products (derivaties of ethylene oxide & Primene amines) describes reaction products of Primene JM-T with ethylene oxide. Suggests principal uses. Bulletin on calcium acrylate describes polymerization in presence of catalyst to water-insoluble & rubber-like gel. For soil stabilization, road surfacing, etc. Rohm & Haas Co.

16 **Solvent Resistant. Grease.** Keystone Lubricating Co. announces a grease capable of withstanding the effects of petroleum solvents. Called lubricant A-9, substance is said to be impervious to gasoline, naphtha, or any type of hydrocarbon liquid or gas. Operating range 20° F. to 400° F.

17 **Organic Chemicals.** Eleven new organic chemicals including Squalene a hydrocarbon, in addition to more than 3,500 Eastern Kodak Co. chemicals. Squalene is distilled by DPI from liver oil of basking shark. Colorless with iodine value of 371, boiling point 330° C. at atmospheric pressure. Bulletin.

18 **Soluble Silicates & Silico Sol.** (18) Philadelphia Quartz
19 Co. anhydrous sodium metasilicate & sodium orthosilicate called Metso Anhydrous & Metso 200. Metso Anhydrous is strongly alkaline detergent for heavy-duty cleaning in metal industries, etc. Metso 200 designed for cleaning operations requiring extra strong alkaline activity. Leaflets on both. (19) Instruction sheet for conducting jar tests using activated silica sol as coagulating aid. Instructions for clarification of special water conditions included.

BULLETINS

20 **Air Filters.** Staynew automatic filters designed for large air volumes described & illustrated in bulletin from Dollinger Corp. Engineering & performance data for wide range of sizes. Cutaway views.

21 **Stainless Steels.** Plates, heads, discs, bars, sheets, etc. of stainless steel available from G. O. Carlson, Inc. Illustrated in folder. Pertinent data.

22 **Storage Tank & Tank Car Valves.** American Car and Foundry Co. illustrated booklet on storage tank & tank-car valves. Schematic diagrams, plus sections on relief valves, tank-car valves, flow rate test facilities, installation & servicing.

23 **Polyethylene Valves.** Vanton Pump & Equipment Corp. valves fabricated with polyethylene-polyisobutylene disc. For use with highly corrosive fluids, such as hydrochloric, hydrofluoric, sulfuric & nitric acids; others listed in folder. Schematic diagrams.

24 **Mercury Switches.** Protected, heavy duty, general use, plus small & sensitive mercury switches described in Micro Switch division of Minneapolis-Honeywell Regulator Co. catalog. Dimensions, descriptions, electrical rating, etc. Application aids & technical data.

25 **Steam-Jacketed Valves.** Everlasting Valve Co. valves for use with heavy petroleum, coal tar, chemical products, etc. are subject of folder. Sizes 1½ to 6 in. for pressures to 150 lb./sq.in. gauge. Cross sections, features.

26 **Bin Level Indicators.** Used for indicating levels of granular, pulverized & semi-liquid materials stored in tanks, silos, etc. Catalog from Bin-Dicator Co. Pressure actuated. Warning signals accessory available. Book includes cutaway views, wiring diagrams, data.

27 **Process Control Instruments.** Wheelco Instruments division Barber-Colman Co. indicators, controllers, recorders described in bulletin containing illustrations & details.

28 **Gearmotors.** Complete line of Westinghouse Electric Corp. Life-Line gearmotors described in illustrated booklet. Ratios for single, double & triple reduction types given and other data. Designs for special requirements described.

29 **Oil Diffusion Vacuum Pumps.** Data sheet from Consolidated Vacuum Corp. on high vacuum oil diffusion pumps. Sizes from 2 in. diam. speed 60-l./sec. to 32 in. diam. & speed of 19,000-l./sec. Ultimate pressure of $5 > 10^{-7}$ mm. Hg. at 250° C. Discusses fractionation, speed, baffles, etc. Complete specifications & performance data.

30 **Temperature Regulating Valves.** Bulletin describing design & operation features of Spence Engineering Co., Inc., pilot-operated temperature regulating valves. Steam pressure is regulated for delivery according to temperature need. Cutaway view, construction features, parts. Easily maintained, tight shutoff.

31 **Proportioning Pump.** Diaphragm-type controlled volume pumps by Lapp Insulator Co., Inc. described in bulletin. No stuffing box required. Used as chemical feeder, meter, filling machine or sampler. Manual & automatic types. Data.

32 **Reducing Atmosphere Analyzers.** Leaflet from Arnold O. Beckman, Inc. describes method and equipment used for continuous analysis of oxygen. Adaptable for controlling flow, etc.

33 **Laboratory Ovens.** Electric ovens & furnaces together with related equipment by Claud S. Gordon Co. Automatic control, U.l. approved, sensitivity ± ½° C., power selector switch, double-wall-type construction, other features, with specifications on each type listed in folder.

34 **Mixers & Centrifugals.** Line of mixing & kneading equipment for chemical process industries from Baker Perkins, Inc. described in illustrated catalog. This heavy-duty equipment is used for pastes, semisolids, & divided solids. Batch & continuous models. Capacity charts, design factors, illustrations included for each type machine.

35 **Tubular Pumps.** Cradle-mounted tubular Moyno pumps from Robbins & Myers, Inc. Handles variety of materials including caustic soda, iron pyrites, mineral oil, hot resin, latex in suspension, etc. Folder gives cross-sectional view, diagrams, tables of capacities & dimensions.

36 **Forged Steel Fittings.** Binder insert catalog of Watson-Stillman Fittings division of H. K. Porter Co., Inc.

Sections on screwed fittings, socket welding fittings, engineering data, standards, materials, pressure-temperature charts, other information.

37 **Agitator Selector.** Capaci-Dial from Eclipse Air Brush Co., a slide-rule type selector which indicates the correct Pneumix agitator for each liquid batch mixing problem. Eleven models indicated; capacities from 5 to 2,400 gal.

38 **Engineers' Handbook.** Mycalex, a molded glass-bonded mica insulator is the subject of an engineers' handbook & catalog from Mycalex Corporation of America. Low electrical loss factor, high dielectric strength, operating temperature stability to 650° F. Characteristics, various grades & uses, machining & fabricating, tables & comparison charts, illustrations included.

39 **Vitro Services.** From Vitro Corporation of America, booklet describes the functions of various branches including design & engineering of process & manufacturing plants, etc.; chemical & physical research plus process development; manufacture of ceramic colors & related products; refining & recovery of rare metals; processing uranium & other ores.

40 **Liquid Cooler Package Units.** Complete self-contained units for use in process liquid coolers. Accessible controls, vibration-absorbing bases, Worthington compressors among features described in folder from Delta Engineering & Conditioning Co.

41 **Tanks.** Engineering, custom-fabrication & installation of tanks described in folder from U. S. Tank division, General Lead Construction Corp.

42 **Free the Atom.** Sourcebook of quotations for editors, commentators, educators, students and others, published by National Association of Manufacturers. Contains twenty questions and answers by national authorities on industrial development of atomic energy by private enterprise.

43 **Bubble Caps.** Revised catalog from Pressed Steel Co. Illustrations of each item, diagrams, sizes, dimensions, all other details.

44 **Water Treatment.** Rohm & Haas Co. brochure, illustrated with two-color flow diagrams, discusses three major classifications of industrial water treatment based on ion exchange. Advantages of various treatment methods interpreted in terms of applications.

45 **Diaphragm Valves.** Series 800 Saunders motor-operated diaphragm valves for tight shut-off, for use with corrosive liquids, solvents, abrasive slurries. Illustrated specification sheet shows features. Minneapolis-Honeywell Regulator Co.

46 **Hydro-Softener.** Dorr Co. illustrated bulletin includes description of physical characteristics, capacities, sizes, operation. Cutaway view details procedure. For all types of softening, removal of 80 to 99% hardness.

47 **Heat Exchanger.** Cooling or temperature control of industrial liquids is subject of Niagara Blower Co. bulletin. Operation shown via diagrams. Installation photographs.

48 **Rupture (Safety) Disc.** Black, Sivalls & Bryson, Inc. rupture disc designed especially for low pressure & highly corrosive applications, where relieving pressure is below range of conventional. Sizes 2 through 10 in., pressure 5 to 100 lb./sq.in. gauge. Bulletin lists tolerance, materials of construction, operational information.

49 **Waste Treatment.** Binder insert brochure in color from Hardinge Co., Inc., on water, sewage, industrial waste treating equipment. Included are circular & rectangular clarifiers. Diagrams, illustrations, plus pertinent data.

50 **Calrod Catalog.** General Electric 1954 edition of catalog on electric heating devices. Indexed by processes & application, contains methods for determining power requirements & heat losses. Include index of related bulletins and data sheets available.

EQUIPMENT

65 **Vacuum Pump.** High vacuum mechanical booster pump for high vacuum stage in low pressure range. Positive displacement pump with mechanical seals, no sealing fluid required. For metallurgical vacuum processing such as refining titanium, zirconium, etc. Kenney Mfg. division, New York Air Brake Co.

66 **Fittings & Pipe.** Fittings catalog and piping handbook from Ladish Co. Seamless welded fittings, forged flanges & forged steel fittings, etc. Special engineering section with technical data & tables for designers. Section on process piping problems including composition, physical requirements of materials, etc.

67 **Bronze Valves.** Bronze valves with Coradur stems to overcome corrosion & dezincification. New alloy 91% Cu, 7% Al, 2% Si, has good machining index, durability, is 10% lighter than brass. Tensile strength more than 95,000 lb./sq.in. R-P&C Valve division, American Chain & Cable Co.

68 **Filter Cloth.** National Filter Media Corp. Teflon filter cloth with high service temperature & chemical inertness. Attacked only by fluorine gas, & molten alkali metals. Inert to other chemical conditions within recommended temperature limits. No moisture absorption; melts but does not burn; resistant to molds, mildew, sunlight.

69 **Metagraphic Instruments.** Metagraphic three-part pneumatically operated instrument system, comprised of a transmitter, receiver & controller. For process installation at desirable operating point. For measure, indicating, recording & control of pressure, vacuum, temperature, liquid level, & flow. Five models. The Bristol Co.

70 **Cementable Teflon.** New Teflon sheets may be permanently cemented with standard adhesives to metal, wood, glass, rubber, leather, ceramics. Has specially prepared surface as homogenous part of sheet. Bulletin gives data on properties, uses, dimensions, etc. United States Gasket Co.

71 **Solution Balance.** Recently redesigned sensitive heavy duty solution balance. Has graduated end reading dial, high strength & aluminum beam. Weighing platform stainless steel. Self-aligning bearings for even load distribution. Metric or avoirdupois standards. Ohaus Scale Corp.

72 **Centrifugal Pump.** Small centrifugal pump, Carpenter 20 stainless for corrosive chemicals or noncontaminating food service, biological & similar applications. Capacity 30 gal./min. Pumps to 24-lb. head with maximum suction lift 20-in. vacuum. Eco Engineering Co.

73 **Flow Meter.** New type flowmeter Xactronic for liquids, Bowser, Inc. Electromagnetic meter permits measurement of variety of conducting liquids, water & aqueous solutions, acids & other corrosive liquids, slurries, molten salts & metals. High pressures & temperatures or high concentration of suspended matter no obstacle. Accuracy 1% of full-scale reading. Linear scale. Six sizes ½ to 2 in.

74 **Low Temperature Dryer.** Surface Combustion Corp. continuous low-temperature dryer. Has Kathabar dehumidification equipment for drying air, & air-distribution system & conveying equipment for raw material. Dryer has heat-exchanger system for delivery of material such as gelatin & glue in suitable form for quick drying, to belt. Sizes 100 to 2,000 lb./hr. Catalog describes construction & operation.

75 **Batch Control.** Stabilog, controller from Foxboro Co. designed to prevent overshoot of a variable during startup of batch processes. Technical report & diagram available. Mechanism is three-way switch tripped by controller output pressure.

76 **Relief Valve.** Ammonia relief valve from Henry Valve Co. for agricultural & industrial chemicals. Has cycled 6902 times without variations in predetermined pressures. Catalog includes new valve with present line of anhydrous ammonia valves & steel fittings. Information with illustrations & diagrams.

77 **Gate Valves.** Lunkenheimer Co. grooved-end gate valves in the 225-lb. W.O.G. King-Clip & 200-lb. iron body bronze-mounted types. Sizes 2½ to 8 in. Require less installation time & eliminate need for grooved-end adapters to connect screw & flanged-end valves in lines where grooved-end pipe & couplings are used.

78 **Integrating Instruments.** New integrating instruments, one current integrating, the other current-squared integrating from General Electric Co. Designed to reduce statistical analysis & slide-rule calculation of quality control problems in continuous processes. For producers of yarn, wire, strip metals, plastics, etc.

79 **Finned Tube.** Delta-Flo fin-tube for extended heat-transfer surface. Fins have triangular ridge near leading edge of fin surface & in front of each row of tubes in multirow coils. Ridge increases air turbulence over entire fin surface reducing insulating film of dead air. Fins are mechanically bonded to coil tubes in a soldering joint. Trane Co.

80 **Steam-Traced Aluminum Pipe.** Aluminum Co. of America Unitrace, an integrally extruded steam traced aluminum pipe. Constructed with steam line as integral part of pipe. Provides permanent heating of pipes handling tar, pitch or various solutions.

81 **Proportioning Valve.** A three-way, cylinder-operated valve with high travel & speed on both pressure stroke & spring return. Kieley & Mueller, Inc. Used as an emergency valve with less than 100 lb./sq.in. on cylinder. Full travel with tight shutoff reached in 0.5 sec. Available in any machineable metal in sizes ½ to 10 in. with Teflon or greased lubricant.

82 **Direct-Fired Air Heater.** Direct-fired air heater for variety of uses in ovens, kilns, dryers. No refractory necessary. A combustion of 90% is completed with the Thermal Research gas, oil or combination burner with heater. Thermal Research & Engineering Corp.

83 **Furan Cement.** Resistance to chemicals, high physical strength, stability & nontoxic qualities claimed for furfuryl-alcohol-type cements by Pennsylvania Salt Mfg. Co. Two formulations—powder Sm, a siliceous filler resistant to most acids & other substances, and powder C, a carbon-type filler for resistance to acid & alkalis.

84 **Plug Valves.** Hamer Oil Tool Co. balanced type 10- & 12-in. plug valves ASA 150 & 300 lb. classes in variety of materials. Chain wheel operation available. Packings may be changed under pressure where line is on stream.

85 **Dissolver.** For difficult solution, dispersion of suspension problems, a combined ultrafast dissolver with slow-speed, paddle-type mixer. Cowles Co., Inc. duplex drive dissolver combines effect of high-speed impeller with gate-type scraper. Sizes 100 to 1,000 gal.

86 **Porcelain Lining Brick.** High density brick by Coors Porcelain Co. Made of alumina, as used in Coors grinding media. Test showed maximum wear of 3/8-in. wear on pebble mill lining after 17,000 hr. Estimated life of 2-in. lining is 70,000 hr. Resistant to all acids except hydrofluoric.

87 (87) Type 1440 pressure controller (nonrecording) for
88 sensitive pressure-vacuum control systems. Handles range from high vacuum to pressures of 10,000 lb./sq.in. Bourdon tube actuated. (88) Type 1450 pilot for displacement-type liquid-level controllers, where torsion tube transmits float movements to reflect changes in liquid level or change in gravity of controlled fluid. Wide throttling range calibrated 0 to 100%. Specific gravity index provided. Black, Sivalls & Bryson, Inc.

89 **Wet-Type Dust Collectors.** UW-3 package units combine exhauster & precipitator components. Illustrated brochure gives additional details plus engineering drawings. The Ducon Co.

90 **Continuous Vacuum Filter.** Oliver United Filters, Inc. bulletin. Featured is wedge-shaped sectored-disc construction, consisting of sectors covered with suitable filtering medium & assembled around a center shaft. Details of construction, operation, sizes, advantages listed.

91 **Kolmetal Coatings.** Emjay Maintenance Engineers bulletin on cold-aluminizing for prevention of corrosion & prolonging service. Recommendations for application to storage tanks, other information.

92 **Fluorocarbon Plastic.** Fluoroplast molded bars & cylinders, also extruded rods & tubing. Reprocessed 100% tetrafluorethylene plastic. United States Gasket Co.

93 **Resin Cement.** Improved synthetic resinous bonding cement for brick & tiles from Ceilcote Co. Good workability & longer pot life, providing longer work time before set, regardless of temperature. Withstands acids, alkalis, solvents, live steam.

94 **Neoprene Coating.** Bulletin describing uses & application of first air-curing, liquid neoprene protective coating GACO N-700 from Gates Engineering Co. May be applied by roller, brush, spray, & requires no accelerator.

95 **Concrete Flooring Process.** Concrete & metal-chip composition Dynapakt said to outwear plain concrete surface 4:1 for use as concrete flooring available from Flash-Stone Co. Bulletin covering applications, etc.

96 **Infrared Lamp.** New-type infrared lamp from G. E. Co. Compact tubular shape, slightly larger in diameter than a cigarette & made of fused translucent quartz. Energy concentration four times that of popular 250 w. infrared bulb. Thermal shock resistant. Sizes 500 & 1,000 w.

97 **Metagraphic Instruments.** The Bristol Co. three-part pneumatically operated instrument system comprising transmitter, receiver, controller. Universal 3 to 15 lb./sq.in. pressure signal interconnects units regardless of where variable is being transmitted. Full plug-in service. Strip-chart recorders & indicators quickly interchangeable without loss of signal or control.

Industry Demand for Chemical Engineers Exceeds Demand for Chemists

The net increase in chemical engineering staffs in the chemicals, petroleum, and rubber industries combined during 1948-53 was about 50% greater than was the increase in the number of chemists employed, the preliminary report of a survey by the Bureau of Labor Statistics shows. So rapid has been the increase that January, 1953, employment totals for the companies surveyed (see table on page 60) show that only in the chemicals industry are there still more chemists than chemical engineers (46% more); in the petroleum field the number of chemical engineers exceeds the number of chemists by almost 32%; and in the rubber industry employment of the two groups is almost equal. The report below is a detailed outline of the facts uncovered by the Government survey.

Employment of chemical engineers during the period 1948-1953 rose steadily in the chemicals, petroleum, and rubber industries, exceeding that of chemists, according to the preliminary report of a survey on the demand for chemical engineers and chemists in these industries conducted by the Bureau of Labor Statistics during the summer of 1953. Chemical engineers employed rose by 45% in the chemicals industry, 40% in petroleum, and 26% in rubber during the 1948-1953 period. The companies reporting indicated that the trend would probably continue throughout 1953, the number of 1953 chemical engineering graduates needed being nearly one third greater than the number hired in 1952, which meant that with the drop in the total number of chemical engineering graduates from 1952 to 1953, the proportion of graduates to be recruited in 1953 was about two thirds greater than was actually hired in 1952. For chemistry graduates, where there was little difference in the total number of graduates in 1952 and 1953, the proportion was about the same.

Reasons for Increase

Within the three industries studied, which together employ about three fifths of all chemical engineers and nearly half of all chemists in the United States, the greatest percentage gains in employment during 1948-1953 occurred in research and development, administration, and "other" activities in chemicals companies and in technical sales and "other" activities in petroleum. Growing complexity of products and processes was the factor most often emphasized by company officials as the reason for recent expansion in the chemical engineering staffs. Increasing mechanization and instrumentation, such as the shift from batch to continuous processing, also contributed, these "advances in methods of processing having been particularly influential in increasing requirements for chemical engineers in design and supervisory work," according to the report. Other factors, such as competition, the excess profits tax (which permitted economical expansion of research activities), and mergers and amalgamations, also added to the increase, although mergers occasionally consolidated the employment of technical staffs.

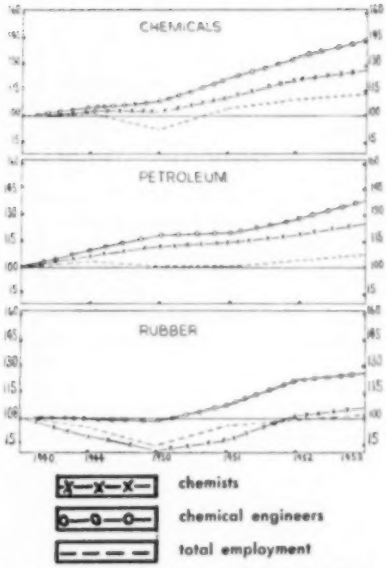
Areas Favored

The areas of employment reported as demanding the largest number of chemical engineers were research and development (43%) and production (34%) in the chemicals industry, refining operations in the petroleum industry (44% as compared with 34% in research and development), and in the rubber companies, production with research second. In the rubber companies a trend toward greater utilization of chemical engineers over chemists in production activities was noted.

Manpower Shortages

Despite the general increase, all companies in the petroleum industry had hard-to-fill vacancies for chemical engineers, and slightly less than half the chemicals and rubber companies reported similar difficulties. In over half the reporting companies, the report stresses, "going or proposed activities were hampered or curtailed between 1948 and 1953 by manpower shortages in the chemicals profession," research and development being most affected because production departments had to be given priority in recruitment and occasionally personnel had to be shifted from research to production work. The scarcity of professional personnel naturally affected most of the large companies, about 85% of the chemicals companies with 15,000 or more employees having reported hampering of operations because of personnel shortages. In many firms the demands of the defense program aggravated the situation. Long-range research in some cases had to be suspended, for although research ideas and funds were available, personnel was not; thus frequently the marketing of new products was delayed and expansion plans had to be revised.

In the groups unaffected by the manpower shortages (nearly three fifths of the total number reporting), the com-



Employment trends in the chemicals, petroleum, and rubber industries (1948-53).

panies were either very small or did not expand their operations during 1948-1953 or were able successfully to train technicians to carry on the more routine tasks and thus free professional personnel.

Replacements

Although expansion was the largest factor in the increased employment of chemical engineers and chemists, replacements also contributed to the demand; for 1953 it was estimated that about 30 to 50% of the professional personnel hired would be needed to fill vacancies. These figures, however, as the report cautions, include transfers from one company to another, which do not represent manpower lost to the industry. It is estimated that the rate of deaths and retirements among chemical engineers and chemists is only about 1½% annually. The report states that "no statistics are available on transfers to other occupations, but the rate of such transfers is believed to be very low in these professions."

Education

In the matter of advanced degrees it was found that chemical engineers were behind chemists, about two fifths of the chemists in the chemicals and petroleum industries holding Ph.D.'s or master's degrees, compared with about one fifth of the chemical engineers in the chemicals industry and one fourth in petroleum. Only one fourth of the chemists and one tenth of the chemical engineers in the rubber companies reporting had advanced degrees, possibly because of the importance of on-the-job training that permits the hiring largely of new graduates.

(*Continued on page 60*)

EMPLOYMENT OF CHEMICAL ENGINEERS AND CHEMISTS AS OF JANUARY 1953

	All Employees	Chemical Engineers	Chemists
All three industries	827,194 (80)	14,586 (90)	18,328 (89)
Chemicals	437,451 (64)	10,007 (73)	14,635 (72)
Petroleum	233,611 (9)	3,468 (9)	2,621 (9)
Rubber	156,132 (7)	1,111 (8)	1,072 (8)

Figures in parentheses indicate number of companies reporting.

Background of the Survey

The three industries selected for the survey require more scientists and engineers than do most other branches of manufacturing. Of the three, chemicals led, companies in this branch employing 35,000 of the 55,000 scientists and engineers covered by the survey; chemical engineers and chemists constituted about two thirds of the professional staffs. In rubber, the number of chemical engineers and chemists about equalled the number of other types of engineers and scientists, and in the petroleum field there were about 60% more other types of professional personnel than chemical engineers and chemists.

The companies included in the survey were selected from a list compiled by the Bureau of Old Age and Survivors Insurance as of March, 1950. Only companies whose primary production was in the chemicals, petroleum, or rubber industry were included, and the survey was limited to firms with headquarters in New York, Chicago, Philadelphia, Pittsburgh, St. Louis, Cleveland, Akron, and a few cities in Ohio and Michigan. All companies with as many as 500 employees were included, plus limited numbers of small- and medium-sized firms. The survey covered however most large firms in these industries in the United States. Interviews were held with 132 companies, and 90 firms sent in usable statistical data—73 in the chemicals industry, 9 in petroleum, and 8 in rubber. These companies represented well over half of the total sales in the industries estimated for 1952.

In final form the report will include besides additional data on the items of the preliminary report, a detailed analysis of possible methods of estimating requirements for chemical engineers and chemists, factors influencing research expenditures, and the utilization and recruitment of semiprofessional technicians.

ENGINEERS' SOCIETY PROTESTS SERVICE BIDS

A protest to James F. Byrnes, governor of South Carolina, was issued recently by the American Society of Civil Engineers on the matter of advertising for competitive bids for engineering services. The protest, in the form of a telegram, was made public last month by William N. Carey, executive secretary of the society. An earlier protest to the same state, which had received the reply that the South Carolina State Highway Department intended to continue the procedure, impelled a renewed declaration of society policy at its convention. Attention was drawn to the section of the Society's Code of Ethics which states, "It shall be considered unprofessional and inconsistent with honorable and dignified bearing for any member . . . to participate in competitive bidding on a price basis to secure a professional engagement."

The telegram called attention to the policy statement, which had been mailed to the governor earlier, and suggested that the highway department follow procedures used by other government agencies, both state and Federal.

NATIONAL MEETING REPORT

(*Continued from page* 38)

To remedy this situation J. A. May and J. C. Frank (Dow Chemical) reported on observations of large diameter (10-ft.) commercial towers in E. E. Lindsey's (Univ. of Mass.) general technical session.

TRAINING IN INDUSTRY OF YOUNG CHEMICAL ENGINEERNG GRADUATES was given a thorough discussion from two points of view during the Sunday afternoon panel discussion by A. V. Flint (General Electric) and G. J. Hutzler (Rohm & Haas), with J. K. Hayes (Monsanto) having the role of moderator. G.E. uses the formal system which entails rotation of the new employee to the various regional facilities, during which period he retains the status of trainee. On the opposite side Rohm & Haas puts the man into a job where he stays for a long enough time to begin feeling like a full-fledged employee before he is moved to something offering either broader experience or better opportunity.

ONE OF THE MOST THOROUGH RÉSUMÉS OF EUROPEAN ELECTROLYTIC CELLS was presented by N. A. J. Platzer (Monsanto), who has had eleven years of direct contact with European plants as a chemical engineer.

JUDGES CHOSE THE A. S. FOSS AND J. A. GERSTER PAPER—LIQUID FILM EFFICIENCIES ON SIEVE TRAYS —AS THE BEST OF THE MEETING. The paper reported a study of plate efficiencies of the popular sieve type of distillation and absorption trays.

FURTHER HELP FOR THE CHEMICAL ENGINEERING DESIGNER. In the field of gas absorption most studies on flow systems in packed towers for the transfer of material between phases has been countercurrent. W. S. Dodds, L. F. Stutzman and B. J. Sollami (Northwestern Univ.) report on an extensive cocurrent study . . . . Packed column performance was studied by H. L. Shulman, C. F. Ulrich, and N. Wells (Clarkson College). . . . F. M. Tiller (Lamar State College) developed analytical equations for constant rate filtration operations. . . . A method said to be useful for the scale-up design of pipe-flow systems was reported by E. B. Christiansen, N. W. Ryan, and W. E. Stevens (Univ. of Utah).

DISTILLATION — FULLY AUTOMATIC —IN SMALL SCALE is readily possible in a 2×78-in. column setup described by G. A. Latinen (Monsanto).

AS A CONVENTION CITY, SPRINGFIELD CAN'T BE EXCELLED if one judges by the warmth of welcome tendered by Mayor Brunton during the opening ceremonies presided over by Frank E. Reese (Monsanto), arrangements co-chairman. (*The End*)

CONKEY EQUIPMENT DIVISION OF C.B.&I.

Chicago Bridge & Iron Co. announced recently plans to fabricate all Conkey equipment in its plants in Birmingham, Chicago, Salt Lake City, and Greenville, Pa. The new division, to be known as the Conkey Equipment Division, with headquarters in New York, will be headed by H. M. Hunter, who formerly was in charge of engineering and sales for Conkey Equipment.

LACK OF TARIFF CAUSES PLANT ABANDONMENT

Diamond Alkali Co. has announced plans to abandon production of refractory periclase at its Painesville, Ohio, plant because of the competition offered by less expensive materials imported from Europe. The Painesville plant has been manufacturing the product since 1948. It was emphasized that other operations at Painesville would not be affected, and plans are being made to reassign as many employees as possible.

GERMAN PERIODICAL REESTABLISHED

The first issues of the Frankfurt edition of *Zeitschrift für Physikalische Chemie, Neue Folge,* are now being published by Akademische Verlagsgesellschaft m.b.H., Frankfurt am Main, Germany. The new series is the lawful continuation of the magazine that was founded in 1887, according to its publishers, who stress that contents of the May issue (Vol. 1, No. 1/2) are not identical with those of a periodical released under the same name in Leipzig in the Eastern Zone. Inquiries about the magazine should be addressed to the publishers at Holbeinstrasse *25-27,* Frankfurt.

I.B.M. HAS NEW DATA-PROCESSING MACHINE

The newest electronic data-processing machine to be released by International Business Machines Corp., the "702," was announced last month. Containing a central arithmetical and logical unit capable of performing more than 10 million operations an hour, the 702 will be used in such manufacturing industries as chemicals and plastics, abrasives, automobiles, aircraft, steel, petroleum, and electrical apparatus. Each reel of magnetic tape has a capacity roughly equivalent to all the numbers in the Manhattan telephone directory and can write answers at the rate of 15,000 characters a second. Delivery of these giant brains, which will be rented to customers, is scheduled to begin in 1955.

NEW REFINING PROCESS HEATS IN THE REACTOR

A method that eliminates much of the external heat equipment usually needed in refining units has been developed by Standard Oil Development Co., which calls the process Model II Fluid Hydroforming. In the process small inert particles are circulated with the catalyst. The carbon accumulating on the catalyst during conversion of the virgin gasoline into high-octane-number fuel is burned off in another part of the unit, thereby heating the inert particles. Larger and heavier than the catalyst, the particles move much more speedily and continuously carry heat to the reactor.

The new process is expected, the company stresses, to do away with many of the compressors and furnaces needed for hydroforming as it reduces the need for about 60% of the heat supplied through external equipment. The new process will be licensed to the industry.

STUDENTS ENTER INDUSTRY FOR A DAY

The workings of a large-scale chemical plant were explained to a group of college students under a program sponsored by the Diamond Alkali Co. and the Agricultural and Mechanical College of Texas. Originated by W. J. Butler, assistant general manager at Diamond Alkali, the plan called for the assigning of each student to a specific Diamond staff member, with whom he went through the day. Production and maintenance, buying and selling, personnel practices, and troubleshooting were some of the activities on which the students obtained first-hand information, according to J. D. Lindsay of the Chemical Engineering Department of the college, who with Dean H. W. Barlow of the School of Engineering set up the academic end of the program.

POWER GROUP TO STUDY REACTOR IN NORTHWEST

The first nuclear power study to be made in the Northwest will be undertaken by five utility companies with a view toward designing and constructing a nuclear reactor for the production of electric power. As is usual with such a project, the study will run for one year, at the conclusion of which the group will report its findings to the Atomic Energy Commission and make recommendations. All costs of the study will be borne by the companies.

The firms taking part in this project are the Montana Power Co., the Washington Water Power Co., the Pacific Power and Light Co., the Portland General Electric Co., and the Mountain States Power Co.

CANDIDATES FOR MEMBERSHIP IN A. I. Ch. E.

The following is a list of candidates for the designated grades of membership in A.I.Ch.E. recommended for election by the Committee on Admissions.

These names are listed in accordance with Article III, Section 7, of the Constitution of American Institute Chemical Engineers.

Objections to the election of any of these candidates from Active members will receive careful consideration if received before July 15, 1954, at the Office of the Secretary, A.I.Ch.E., 120 East 41st Street, New York 17, N. Y.

Applicants—Active

Altsheler, Wm. B., *Louisville, Ky.*
Betzig, Harry M., *Homewood, Ill.*
Boyd, David M., Jr., *Clarendon Hills, Ill.*
Brown, Robert Mulnix, *Walnut Creek, Calif.*
Byck, Lawrence Charles, Jr., *New Canaan, Conn.*
Cholette, Albert, *Quebec, P.Q., Canada*
Cornelius, Edward B., *Swarthmore, Pa.*
Daley, Joseph F., *Mendham, N. J.*
Dewey, George D., *New Castle, Del.*
Fisher, J. H., *Nanaimo, B.C., Canada*
Forsberg, Hugh C., *Louisville, Ky.*
Fritzsche, Reinhold H., *Kew Gardens, N. Y.*
Frye, Alva L., *St. Paul, Minn.*
Grubb, W. G., *Kingsport, Tenn.*
Hegstad, R. G., *Argo, Ill.*
Helbig, W. A., *Tuckahoe, N. Y.*
Iliff, James E., *Park Forest, Ill.*
Jackson, Arthur J., *E. Hartford, Conn.*
Karwan, Stephen M., *Newark, N. J.*
Keamy, Mitchell F., Jr., *New York, N. Y.*
Kelley, James C., *Pittsburg, Kans.*
Kircher, Morton S., *Niagara Falls, N. Y.*
Laitner, Robert V., *Trenton, Mich.*
Lynch, Edward P., *W. Chicago, Ill.*
Machmer, William L., Jr., *New York, N. Y.*
Maddocks, Robert R., *Tulsa, Okla.*
Mayer, Richard G., *Springfield, Mass.*
Minich, Herbert L., *Linden, N. J.*
Morel, R. W. F., *San Jose, Calif.*
Nielsen, Maurice F., *Chicago, Ill.*
Pabich, Harold L., *Argo, Ill.*
Pater, A. S., *Tonawanda, N. Y.*
Rounds, Charles D., *Wilmington, Del.*
Schultz, Joseph F., *Texas City, Tex.*
Schustek, George W., *Whiting, Ind.*
Schuyler, R. L., *Wilmington, Del.*
Shaw, Gail L., *Chehalis, Wash.*
Sweny, John W., *El Cerrito, Calif.*
Thompson, John F., *Anniston, Ala.*
Verner, H. Grey, *Homer, N. Y.*
White, Reno J., *Flossmoor, Ill.*
White, Warren T., Jr., *Harrisonburg, Va.*
Whitson, John W., *Baton Rouge, La.*
Williams, William L., III, *Abilene, Tex.*
Zahray, Walter K., *Ringwood, Ill.*

Applicants—Associate

Burg, Walter V., *Toledo, Ohio*
Elliston, R. H., *Pawhuska, Okla.*
Friend, Walter F., *New York, N. Y.*
Paull, John O., *Los Angeles, Calif.*
Tomlinson, C. W., *Pasadena, Tex.*

Applicants—Junior

Abbanat, Robert F., *Chicago, Ill.*
Ambrose, William D., *Eurega, Mont.*
Atz, Robert W., *Monterey Park, Calif.*
Belaga, Myron W., *Dayton, Ohio*
Bergeron, Charles R., *Baton Rouge, La.*
Bond, Donald L., *Westmont, Ill.*
Bostick, Edgar E., *Akron, Ohio*
Brian, Ross F., *Decatur, Ill.*
Brown, Donald V., *Schenectady, N. Y.*
Chen, Edward Chi-Kwang, *Terre Haute, Ind.*
Cracraft, George A., *Louisville, Ky.*
Cramer, Robert H., *Woodbury, N. J.*
Crnkovich, Roman J., *Ridley Park, Pa.*
Elishewitz, Saul, *Philadelphia, Pa.*
Embrey, Nelson S., *Amherst, Va.*
Everson, Carl H., *Elmhurst, Ill.*
Gamble, Paul E., *Neshanic, N. J.*
Goolsbee, James A., *Houston, Tex.*
Hagan, John J., *Tulsa, Okla.*
Hart, Robert Allen, *Charleston, W. Va.*
Hausman, Robert F., *Pittsfield, Mass.*
Hegedus, John S., *New York, N. Y.*
Hill, Donald F., *Woodbury, N. J.*
Horne, William R., *Elkton, Va.*
Huntley, Allan R., *Dhahran, Saudi, Arabia*
Kean, L., *New York, N. Y.*
Klipstein, David H., *Orangeburg, N. Y.*
Knepper, William A., *Pittsburgh, Pa.*
Lieberson, Nathan G., *Dorchester, Mass.*
Liptak, Ronald C., *Yonkers, N. Y.*
McGinnis, Claude A., *Chattanooga, Tenn.*
Meier, Henry J., *St. Louis, Mo.*
Miller, B. Z., *Wilmington, Del.*
Naphtali, Leonard M., *Dearborn, Mich.*
Nauss, James E., *Calumet City, Ill.*
Parker, John A., *Texas City, Tex.*
Pellizzi, Elizabeth, *Bayshore, L. I., N. Y.*
Pickel, Thomas W., Jr., *Baytown, Tex.*
Pickelmann, Russell M., *Midland, Mich.*
Robertson, George O., *Kingsport, Tenn.*
Rosenthal, M. W., *Oak Ridge, Tenn.*
Rownd, R. M., *Midland, Mich.*
Ryan, G. Thomas, *Texas City, Tex.*
Savoca, Joseph I., *Woodstown, N. J.*
Schwaig, Robert H., *Alton, Ill.*
Seador, John L., *Ballston Spa, N. Y.*
Soerhuus, Oddmund, *Charleston, W. Va.*
Sullivan, Paul M., *Hyattsville, Md.*
Talty, Robert D., *Hammond, Ill.*
Taylor, Arkle D., *Akron, Ohio*
Travers, Richard J., *Levittown, L. I., N. Y.*
Tunison, Donald E., Jr., *Corpus Christi, Tex.*
Turner, Marshall, *Chicago, Ill.*
Upington, Gaylord W., *El Segundo, Calif.*
Valentine, William A., Jr., *Arnold, Pa.*
Vander Hyde, Norman J., *Edwards, Calif.*
Van Vooren, E. H., *Houston, Tex.*
Whitley, Donald L., *West Columbia, Tex.*
Wright, William H., *Atlanta, Ga.*
Yeager, Robert A., Jr., *Akron, Ohio*
Zaffrann, Ralph, *Fredrick, Md.*
Zizza, Michael, *Massapequa, L. I., N. Y.*

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MARGINAL NOTES

Enlightening Summary Data

Investigation of Rates and Mechanisms of Reactions. Edited by S. L. Friess and A. Weissberger. Interscience Publishers, Inc., New York (1953), 760 pp. $13.50.

Reviewed by H. E. Hoelscher, Asst. Professor, Chemical Engineering, John Hopkins University, Baltimore, Md.

This is the eighth in the Technique of Organic Chemistry series. It contains ten chapters devoted to a review-like presentation of the kinetics and mechanisms of organic reactions. This volume concerns much that is of interest and value to the chemical engineer. The contributors have done an excellent job of condensing and summarizing much experimental and theoretical information on a broad subject and have presented the subject in a manner which should prove useful to one working in the field of kinetics, whether chemical engineer or chemist. The first chapter dealing with the general theory of rate processes, is perhaps the only chapter attempting to cover too much in too few pages. In essence, the entire basic structure of the subject of chemical kinetics is presented in thirty-six pages—an obviously impossible task. Nonetheless, the chapter outline is well selected and the material presented should prove a quick and perhaps effective review for one forced to enter the field of experimental kinetics after a lapse of some time.

The second and fourth chapters are particularly well done and should be given special attention. The second chapter, which is devoted to the problems encountered in obtaining acceptable rate data, presents a summary of the experimental difficulties one might expect in approaching a kinetic study. The fourth, on the evaluation and interpretation of rate data, presents information on the handling of experimental results and on the mathematical treatment of rate data. Here the subject is one of considerable value, and an adequate presentation for ready reference and study by student and experimenter has been badly needed for some time.

The third chapter on special experimental techniques gives valuable information to anyone considering the initiation of kinetic studies in the laboratory. The first part, which is devoted to the use of tagged atoms and isotopes, may be of special interest as a modern approach to analysis. The chemical engineer should find increasing use of tracer and tagged atom techniques for analysis in research and, even, pilot plant studies. This chapter, by no means

an exhaustive treatise on the subject, provides an easy starting point from which to become familiar with this field. The remainder of the chapter, however, is of much more interest to the chemist than the engineer. Chapters 5 and 6 on homogeneous-gas and liquid-phase reactions respectively and chapter 7 on homogeneous catalysis, present an adequate review of these topics. The remainder of the book on polymer reactions, biological reactions and rapid reactions, is quite specialized.

The one glaring omission in the text is the subject of catalytic vapor-phase reactions, and the entire problem of heterogeneous catalysis has been ignored.

In general the volume should be a valuable addition to the library of chemical engineers, as well as chemists. The volume is well outlined and well indexed.

The Measure of All Things

Temperature Measurement in Engineering, Vol. I. H. Dean Baker, E. A. Ryder, and N. H. Baker. John Wiley & Sons, Inc., New York (1953), 179 pp. $3.75.

Reviewed by Charles E. Sanborn, Shell Development Co., Emeryville, Calif.

The measurement of temperature is important in many branches of engineering and is frequently encountered in chemical engineering. This book is the first of two volumes intended "to provide in convenient non-mathematical form the information necessary to the engineer who wishes to measure temperature," and stressing the "specific details essential to actual execution," the authors have attained this objective satisfactorily. In many respects the book is reminiscent of a laboratory manual.

This first volume deals chiefly with the measurement of internal temperatures in solids, hence primarily with thermocouple technique as the most widely useful method of making such measurements. The projected second volume will consider subjects of more interest to chemical engineers, e.g., measurement of the temperature of surfaces, of flowing liquids, gases, gas-liquid, or gas-solid mixtures. The first four chapters are introductory to the complete work of two volumes. The concept of temperature and the various temperature scales are dealt with in Chapter 1. Various methods of measuring temperature, ranging from gas- or liquid-filled thermometers, through electric-resistance thermometers and thermocouples, to radiation and optical pyrometers and pyrometric cones are considered in Chapter 2. Precision requirements and errors are discussed in Chapter 3 and

conditions affecting temperature measurements are considered in Chapter 4. The remainder of the volume is devoted to various aspects of thermocouple installation and operation. The thermocouple circuit is considered in Chapter 5, starting with thermoelectric power. Indicating instruments are discussed briefly in Chapter 6, and design calculation techniques, principally heat-transfer effects, are considered in Chapter 7. Installation design types are considered in Chapter 8, including detailed information on welded, soldered, and cemented junctions. Chapter 9 is concerned with an auxiliary technique, that of drilling the deep, small diameter holes required for thermocouple installations for the measurement of the internal temperatures of solids. Special materials, for use when the installation is subject to severe conditions such as high temperature or corrosive environment, are discussed in Chapter 10. Cemented installation designs are considered in Chapter 11. Chapter 12 covers special installations for use in the presence of a temperature gradient.

References included with each chapter are rather spotty, in some cases they are extensive, in others sketchy. The text is well annotated in those cases where extensive references are given.

Books Received

Graphics in Engineering and Science. A. S. Levens. John Wiley & Sons, Inc., New York (1954), viii+696 pp. $7.00.

Calculations of Analytical Chemistry, 5th edition, International Chemical Series. Leicester F. Hamilton and Stephen G. Simpson. McGraw-Hill Book Co., Inc., New York (1954), xii+340 pp. $5.00.

General Chemistry. A Topical Introduction. Eugene G. Rochow and M. Kent Wilson. John Wiley & Sons, Inc., New York (1954), xiii+602 pp. $6.00.

Lubrication of Industrial and Marine Machinery, 2nd edition. William G. Forbes. Revised by C. L. Pope and W. T. Everitt. John Wiley & Sons, Inc., New York (1954), viii+351 pp. $6.50.

Compounds with Condensed Thiophene Rings. The Chemistry of Heterocyclic Compounds Series Vol. 7. H. D. Hartough and S. L. Meisel. Interscience Publishers, Inc., New York 1954), xv+515 pp. Single copy $16.50, subscription price $15.00.

Chemistry of the Defect Solid State. Methuen's Monographs on Chemical Subjects. A. L. G. Rees. John Wiley & Sons, Inc., New York (1954), viii+136 pp. $2.00.

ZEISBERG AWARD WINNERS

Presentation to the three winners of the annual F. C. Zeisberg Memorial Award for excellence in report writing by students in chemical engineering was made during the April 27 dinner meeting of the Philadelphia-Wilmington Section of A.I.Ch.E. at the Penn-Sherwood Hotel, which climaxed an all-day meeting on "Distillation in Practice."

H. C. Mouwen

First-place winner was Herman C. Mouwen, a senior chemical engineering student at Lehigh University. C. Roger Williams, a senior at Princeton University, won the second award. The third award went to Martin Brill, a senior at Drexel Institute of Technology.

C. Roger Williams

The Zeisberg Award honors the memory of Fred C. Zeisberg, President of the American Institute of Chemical Engineers (1938) and an engineer of the Du Pont Company. He especially encouraged young engineers to write good reports.

Martin Brill

The competition is open to students selected by the following schools: Bucknell University, Drexel Institute of Technology, Lehigh University, Lafayette College, Princeton University, University of Delaware, University of Pennsylvania, and Villanova College. The winners are awarded technical books of their own selection.

A. I. Ch. E. Students with Models a Feature at V. P. I. Conference

Industrial and student curricular club exhibits were an interesting feature of the Fifth Conference on the Advancement of Engineering which took place at Virginia Polytechnic Institute, Blacksburg, Va., April 22-24, 1954. The student A.I.Ch.E. group displayed actual working models (built by the students) of a fluidized unit, double-effect evaporator, and fractionating column as shown in the accompanying illustration. Presiding at the morning session on April 23 of "Engineering's Relationship to Modern Civilization," as the Conference was titled, was Robert H. Miller, president, V.P.I. Association for Advancement of Engineering. J. Louis Reynolds, vice-president, Reynolds Metals Co., was guest speaker. In the afternoon symposia were conducted by student branches of the National Engineering Societies. As its symposium speakers the A.I.Ch.E. group had H. G. McBurney, general superintendent, Baltimore refinery, Esso Standard Oil Co., and Richard E. Herron, chemical engineer, Dow Chemical Co., Freeport, Tex.

GOVERNMENT OPENINGS FOR ENGINEERS

Chemical and other engineering openings with the Federal Government have been announced by the Board of U.S. Civil Service Examiners, Army Chemical Center, Md. The positions, ranging in salary from $5,060 to $10,800 annually, are all available in Maryland, except where an individual examination is announced for a specific agency. In most cases competitors will not be required to report for a written test but will be rated on the extent and quality of their experience and training relevant to the duties of the position in question. Applications or information may be obtained at any post office.

INDUSTRY TEACHES THE TEACHERS IN HOUSTON

The fifth annual industry-sponsored school for chemical engineering teachers in the Southwest was held on May 14 at the Houston refinery of the Shell Oil Co. Under the general subject "Design of a Modern Crude Distilling Unit for Processing Sour Crudes" various members of the Shell processing engineering staff presented such aspects of the topic as laboratory crude evaluation, economic evaluation, process design, selection of pumps and drives, selection of materials of construction, modern instrumentation practices, design of relief valves and dropout facilities, design of crude desalting units and product treaters, and handling and subsequent processing of unit products, reports Kenneth A. Kobe, professor of chemical engineering at the University of Texas.

Twenty staff members from Texas Agricultural and Mechanical College, University of Houston, Lamar School of Technology, University of Oklahoma, Rice Institute, Tulane University, and the University of Texas attended.

SUMMER COURSE IN DISTILLATION

A course for practicing engineers to provide a working knowledge of fundamental principles of the design of distillation and absorption equipment will be offered by the department of chemical and metallurgical engineering of the University of Michigan from July 12 to 23, 1954. Roger H. Newton of the Badger Manufacturing Co. and Robert R. White and Brymer Williams of the university faculty will present such subjects as tray layout and hydraulics, azeotropic and extractive distillation, vapor-liquid equilibrium, and tray calculations. Information on registration may be obtained from the department, 2028 East Engineering Building, Ann Arbor.

STUDENT AWARDS FEATURE ENGINEERS' CONFERENCE

The First Annual Conference for Engineers held on May 7, in conjunction with Alumni Day of the Ohio State University, Columbus, Ohio, was highlighted in the chemical engineering department by the presentation of American Institute of Chemical Engineers student awards in chemical engineering, the National Student Contest Awards of the Central Ohio Section, A.I.Ch.E., and several timely technical papers. Inspection trips through research laboratories and through the Engineering Experiment Station of the university were main attractions also.

William I. Burt, Past President of A.I.Ch.E. and vice-president, B. F. Goodrich Chemical Co., presented Glen F. Althouse with the A.I.Ch.E. Annual Scholarship Award to Ohio State University Student Chapter, as shown in accompanying picture.

Keith Jacobs, Ironsides Co., and chairman, Central Ohio Section, presented the Central Ohio Section Awards to the students, Richard E. Dudley and Richard L. Boggs, whose solutions to the National Student Contest problem were submitted to the Institute. These awards consisted of student membership in the Institute and a year's subscription to C.E.P.

Papers presented during the afternoon included the following subjects: kinetics, chlorination and esterification processes, phase behavior, crude oil evaluation, mass transfer, processing of salt solutions, and aerosols.

The tour through the laboratories featured inspection of chemical engineering operations, process development, and industrial waste treatment.

POLYVINYL CO. ACQUIRED

Acquisition of Colton Chemical Co., Cleveland, by Air Reduction Co., New York, has been announced. The old firm may become a division of the new.

FUTURE MEETINGS AND SYMPOSIA OF A.I.Ch.E.

Chairman, A.I.Ch.E. Program Committee

George Armistead, Jr., George Armistead & Co. — 1200 18th St., N.W., Washington, D. C.

Assistant Chairman

L. J. Coulthurst, Foster Wheeler Corp. — 165 Broadway, New York 6, N. Y.

MEETINGS

Glenwood Springs, Colo., Hotel Colorado, Sept. 12-15, 1954.

TECHNICAL PROGRAM CHAIRMAN: Dr. Charles H. Prien, Head, Chem. Div., Denver Res. Inst., Univ. of Denver, Denver 10, Colo.

Annual—New York, N. Y., Statler Hotel, Dec. 12-15, 1954.

TECHNICAL PROGRAM CHAIRMAN: G. T. Skaperdas, Assoc. Dir., Chem. Eng. Dept., M. W. Kellogg Co., 225 Broadway, N. Y. 7, N. Y.

ASST. CHAIRMAN: N. Morash, Titanium Div., National Lead Co., P. O. Box 58, South Amboy, N. J.

Louisville, Ky., Kentucky Hotel, March 20-23, 1955.

TECHNICAL PROGRAM CHAIRMAN: R. M. Reed, Tech. Dir., Gas Proc. Div., The Girdler Corp., Louisville 1, Ky.

Houston, Texas, Shamrock Hotel, May 1-4, 1955.

TECHNICAL PROGRAM CHAIRMAN: J. L. Franklin, Res. Assoc., Humble Oil & Refining Co., P. O. Box 1111, Baytown, Texas.

Lake Placid, N. Y., Lake Placid Club, Sept. 25-28, 1955.

TECHNICAL PROGRAM CHAIRMAN: L. J. Coulthurst, Chief Proc. Designer, Foster Wheeler Corp., 165 Broadway, New York 6, N. Y.

Annual—Detroit, Mich.—Statler Hotel, Nov. 27-30, 1955.

TECHNICAL PROGRAM CHAIRMAN: T. J. Carron, Supervisor, Chem. Eng. Section, Ethyl Corp., Res. Labs., 1600 West Eight Mile Road, Detroit 20, Mich.

Los Angeles, Calif., Statler Hotel, Feb. 26-29, 1956.

TECHNICAL PROGRAM CHAIRMAN: T. Weaver, Proc. Eng., The Fluor Corp., Ltd., Box 7030, East L. A. Station, Los Angeles 22, Calif.

Annual—Boston, Mass., Hotel Statler, Dec. 9-12, 1956.

TECHNICAL PROGRAM CHAIRMAN: W. C. Rousseau, Proc. & Sales Eng., Badger Mfg. Co., 230 Bent St., Cambridge 41, Mass.

SYMPOSIA

Agglomeration

CHAIRMAN: A. P. Weber, International Engineering, Inc., 15 Park Row, New York, N. Y.

MEETING—Glenwood Springs, Colo.

Uranium Processing and Refining

CHAIRMAN: R. H. Long, Vitro Eng. Div., Vitro Corp., 120 Wall St., New York, N. Y.

MEETING—Glenwood Springs, Colo.

Oil Shale and Shale Oil Processing

CHAIRMAN: W. I. R. Murphy, Pet. & Oil Shale Exp. Station, U. S. Bureau of Mines, P. O. Box 621, Laramie, Wyoming.

MEETING—Glenwood Springs, Colo.

Reaction Kinetics

CHAIRMAN: N. R. Amundson, Dept. of Chem. Eng., Univ. of Minnesota, Minneapolis 14, Minn.

MEETING—New York, N. Y.

Gas Absorption

CHAIRMAN: R. L. Pigford, Div. of Chem. Eng., Univ. of Delaware, Newark, Del.

MEETING—New York, N. Y.

Solvent Extraction

CHAIRMAN: Dr. R. B. Beckmann, Dept. Chem. Eng., Carnegie Inst. of Tech., Schenley Park, Pittsburgh 13, Pa.

MEETING—New York, N. Y.

New Processes Utilizing Moving Beds

CHAIRMAN: N. Morash, Tit. Div., National Lead Co., P. O. Box 58, South Amboy, N. J.

MEETING—New York, New York

Biochemical Engineering

CHAIRMAN: C. W. Weil, Chas. Pfizer & Co., 11 Bartlett St., Brooklyn 6, N. Y.

MEETING—New York, N. Y.

Heat Transfer

CHAIRMAN: R. L. Pigford, Div. of Chem. Eng., Univ. of Delaware, Newark, Del.

MEETING—Louisville, Ky.

Nucleation Processes

CHAIRMAN: D. W. Oakley, Plant Mgr., Metal & Thermit Corp., 1 Union St., Carteret, N. J.

MEETING—Houston, Tex.

Flow of Fluids Through Porous Media

CHAIRMAN: H. Dayton Wilde, Mgr. Res. Div., Humble Oil & Ref. Co., Box 2180, Houston 1, Tex.

MEETING—Houston, Tex.

Photochemical Processes

CHAIRMAN: Prof. J. J. Martin, Dept. Chem. Eng., Univ. of Michigan, Ann Arbor, Mich.

MEETING—Detroit, Mich.

Unscheduled

Centrifugation

CHAIRMAN: J. O. Maloney, Chairman, Dept. Chem. Eng., Univ. of Kansas, Lawrence, Kan.

Extraction of Hydrocarbons for Chemical Use from Pipe Line Gases

CHAIRMAN: E. E. Frye, J. F. Pritchard & Co., 210 W. 10th, Kansas City 5, Mo.

Submitting Papers

Members and nonmembers of the A.I.Ch.E. who wish to present papers at scheduled meetings of the Institute should follow the following procedure.

First, write to the Secretary of the A.I.Ch.E., Mr. S. L. Tyler, American Institute of Chemical Engineers, 120 East 41st Street, New York, requesting three copies of the form "Proposal to Present a Paper Before the American Institute of Chemical Engineers." Complete these forms and send one copy to the Technical Program Chairman of the meeting for which the paper is intended, one copy to the Assistant Chairman of the A.I.Ch.E., Program Committee, address at the top of this page, and one copy to the Editor of Chemical Engineering Progress, Mr. F. J. Van Antwerpen, 120 East 41st Street, New York.

If you wish to present the paper at a particular symposium, request 4 copies of the proposal sending a copy to the Chairman of the symposium.

Before Writing the Paper

Before beginning to write your paper you should obtain from the meeting Chairman, or from the office of the Secretary of the A.I.Ch.E., at 120 East 41st St., New York, a copy of the A.I.Ch.E. Guide to Authors, and Guide to Speakers. These cover the essentials required for submission of papers to the A.I.Ch.E. or its magazines.

Copies of Manuscript

Five copies of each manuscript must be prepared. For meetings, one should be sent to the Chairman of the symposium, and one to the Technical Program Chairman of the meeting at which the symposium is scheduled. If no symposium is involved, the two copies should be sent to the Technical Program Chairman. The other copies should be sent to the Editor's office since manuscripts are automatically considered for publication in Chemical Engineering Progress, or the symposium series of Chemical Engineering Progress, but presentation at a meeting is no guarantee that they will be accepted.

DEADLINE DATES FOR PAPERS

NEW YORK MEETING—August 12, 1954

LOUISVILLE MEETING—November 20, 1954

HOUSTON MEETING—January 1, 1955

LAKE PLACID MEETING—May 25, 1955

DETROIT MEETING—July 27, 1955

LOS ANGELES MEETING—October 26, 1955

BOSTON MEETING—August 9, 1956

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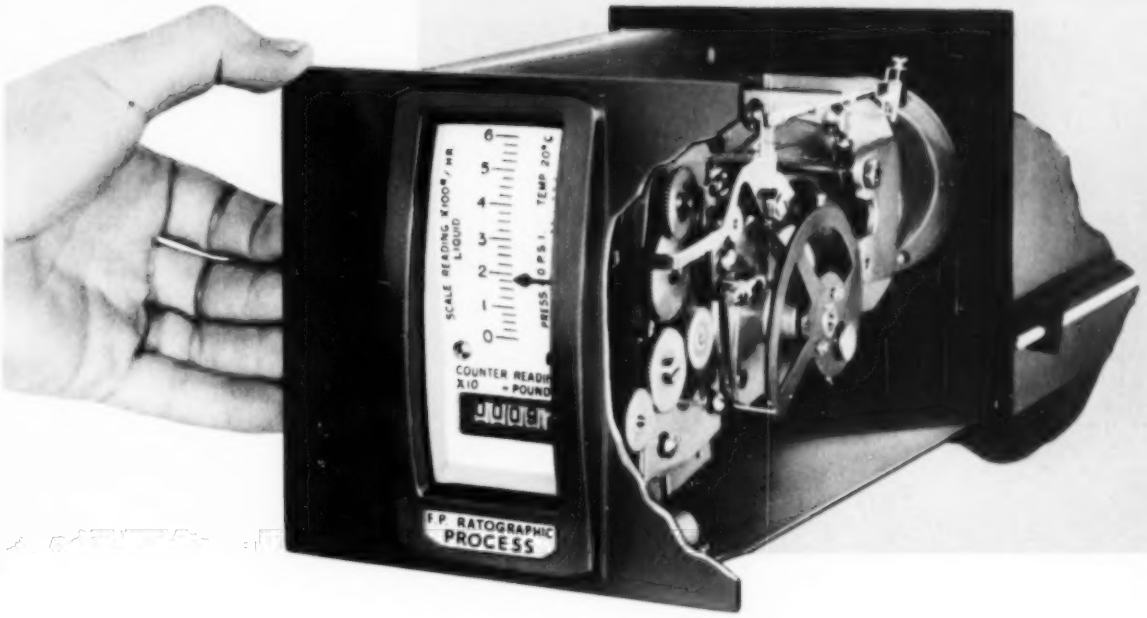

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LOCAL SECTION NEWS

If the criteria of cultural achievement is the enjoyment of and participation in literature, music, and the lively arts, the chemical engineer is more active culturally than his liberal arts prototype. He is primarily a scientist and his problems of existence and social behavior follow the pattern of his fellow scientists. He is well, but not excessively paid.

The supply of engineers is falling and the decrement is believed to be caused by unimaginative and incompetent teaching of mathematics and the sciences in the public school system.

With these words George T. Austin introduced an address under the title "The Engineer As Society's Problem Child and Bonehead" before sixty members and their wives of the Columbia Valley Section, Richland.

Subsequent to this meeting the section held its annual symposium on "Design." An attendance of 140 engineers heard the speakers present a review of the major design problems encountered in nuclear engineering at Hanford, the approach to their solution, and future design trends. The symposium speakers were all members of the engineering department at General Electric Co.'s Hanford Atomic Products Operation. Serving as moderator of the panel of speakers was R. H. Beaton, manager of design section.

Currently underway is a 15-week Chemical Engineering Refresher Course sponsored by the local section. This course is designed to assist the chemical engineer in preparing for the state professional licensing examination given in June of each year. The last two lectures are held open for review of specific subjects on which the class wishes to spend more time. The lecturers are all technical and professional employees of General Electric at Hanford. An enrollment fee of ten dollars has been found adequate to cover the cost of the course, including mimeographed lecture notes, which are furnished to all students. B. L. Lex, reporter for the section, states that H. H. Greenfield ably performed the task of organizing this course, which now has twenty-four students.

The following officers were elected at the April 20, 1954 meeting of the Kansas City Section to serve until May, 1955:

Chairman-elect—W. W. Bodle, J. F. Pritchard Co.

Secretary—H. H. Branine, Midwest Research Institute.

Treasurer—V. V. Valleroy, University of Kansas.

Directors—J. R. Salsbury, Procter & Gamble, P. R. Ducksworth, Phillips Petroleum Co., and L. V. Sorg, Standard Oil Co. (Ind.)

H. M. Steininger, Standard Oil Co. (Ind.) will serve as *Chairman* for the 1954-55 period.

J. O. Maloney remains a member of the Executive Committee as the retiring *Chairman*.

J. B. Rush, former section secretary, sent in a full report on the year's activities. Four meetings preceded by dinner have been held during 1954 at which talks were given on industrial waste problems in a petrochemicals plant, re-use of industrial cooling water, and a process development in the pilot plant.

Members of the Rochester Section took a plant trip on May 5 to the crude oil refinery of Socony-Vacuum Inc., Buffalo, N. Y. A highlight was the outdoor plant construction with a main point of interest being the catalytic reformer. In addition to the gasoline production at this refinery, visitors saw wax, heavy oil and motor oil production. W. H. Eilinger is the reporter for this section.

At the annual meeting of the Ichthyologists (Boston Section) held on April 23, the following officers were elected for the 1954-55 season:

Kingfish (Chairman)—William C. Rousseau, Badger Manufacturing Co.

Mackerel (Vice-Chairman)—Howard H. Reynolds, Dewey & Almy Chemical Co.

Smelt (Secretary)—Arthur G. Smith, Monsanto Chemical Co.

Shark (Treasurer)—Craig W. Angell, Artisan Metal Products Co.

The program of the evening was "An Evening with Doc Lewis." In response to a series of verbal baitings by selected Ichthyologists, the guest of honor, Dr. Warren K. Lewis, related some of the highlights of his career "with the eloquence and sparkle for which Doc Lewis is renowned."

Dr. Lewis asserted that his career in chemical engineering was largely a matter of chance since he had had every intention of returning to the family farm in southern Delaware after completing high school in New England. He continued his studies at M.I.T. to pursue his interest in mathematics and somehow got involved in the application of engineering and mathematics to industrial chemistry. The long up-hill struggle for recognition of the engineering viewpoint in industrial chemistry, which was finally established with the rapid rise of the chemical industry prior to and during World War II, was described with many anecdotes. There is also a reminder to the chemical engineering profession that the original sources of reference for chemical engineering were mostly derived from physics and mechanical engineering, and that chemical engineers today must keep in close touch with developments in these fields.

As a prime figure in the contribution of chemical engineering to the American war effort in two world wars, Dr. Lewis described some of the surprising developments during those periods such as the development of an aniline industry in three months' time, the manifold industrial capacity advantage over the enemy in such materials as mustard gas, and other less known items such as the anti-mustard boot for horses.

The climax of the evening was the presentation of the first "Harengus Rubrus Award," less commonly known as the "Red Herring Award," to Dr. Lewis for his outstanding proficiency in the fields of chemical engineering, teaching, judgment of human talent, wartime contributions, contributions to the chemical industry, business, and investing.

Dr. Lewis concluded the evening with the harengus rubrus lecture on the "Unforgivable Sin." In summation, he was not sure what it was, but suspected it was "Taking One's Self Too Seriously."

A. G. Smith sent us a full report of this unusual meeting.

"What Makes Him Tick?" was the subject of a discourse delivered by Ben Taylor, industrial relations department, B. F. Goodrich Co., before the April 27 meeting of the Cleveland Section. Mr. Taylor outlined and illustrated some of his concepts of human relations. At the dinner at the Fenn Cafeteria twenty-two

were present and at the meeting which followed thirty-seven members and guests were present. David J. Porter, secretary of the section, announces that a later meeting will include a plant tour of the Diamond Alkali Co.

Dwayne Orton discussed "Oral Communications—The Personal Way" before the May 13 meeting of the Western New York Section. Dr. Orton spoke on the same subject before the A.I.Ch.E. Toronto meeting and that talk was enthusiastically acclaimed. He is educational consultant for I.B.M., has been officer and member of many management organizations. H. B. Addoms, secretary-treasurer of the section, announced a forthcoming plant tour through the Ontario Hydro Development.

The development of laminated industrial plastics and recent advances in the field were the highlights of a talk by Ralph K. Witt, associate professor of chemical engineering, Johns Hopkins Univ. given at a joint meeting of the Maryland Section of A.I.Ch.E. and the American Society of Mechanical Engineers on April 26. Mr. Ossermann reports that Dr. Witt also talked about his trip to Stockholm, Sweden, as a representative to the International Conference, which covered standard methods of testing plastics. He then pleased his audience further with an illustrated travelog of his journey through Europe, which he enjoyed at the conclusion of the International Conference.

At its first annual meeting the New Haven Chemical Engineers' Club re-elected the following officers for 1954-55:

Chairman—Walter S. Kaghan, Olin Industries, Inc.

Vice-Chairman—E. Leonard Borg, Naugatuck Chemical Co.

Secretary—Joseph J. Levitzky, Olin Industries, Inc.

Treasurer—Shepherd Lippa, Sponge Rubber Products Co.

Executive Committee—Alan T. Lincoln, American Cyanamid Co.; Raymond W. Southworth, Yale University; Walter C. Wardner, Connecticut Coke Co.; Stanley E. Wilson, Carwin Co.

The club held a testimonial banquet at the Faculty Club on May 25 to honor Professor Barnett F. Dodge of the department of chemical engineering, Yale University. Dr. Dodge is Vice-President of A.I.Ch.E. He has just returned from a tour of teaching in Spain under the direction of the State Department. As an added feature to the dinner, Dr. Dodge showed movies that were taken during his stay in Spain.

An inspection trip through the Galveston-Houston Breweries, Inc., Galveston, Tex., featured the May 21 meeting of the South Texas Section. Louis Autrey, brew master, talked on history highlights and the industrial problems of the brewing industry.

This section is saddened by the death on March 6, 1954, of F. F. Bishop, professor of

chemical engineering at Texas A. & M. College. Though not a member of A.I.Ch.E., Professor Bishop was active in the affairs and doings of the South Texas Section. C. L. Fitzgerald, Jr., states that the section has suffered a definite loss.

Machine calculations and problems applicable were the gist of a talk presented by Messrs. Kimball and Williams of the I.B.M. Co. before a recent meeting of the Texas Panhandle Section. "Piercing the Unknown," the title of the talk, was supplemented by a film depicting the development of the I.B.M. No. 701 calculator.

Whitsel, secretary, informs us that addresses at the two previous meetings covered the subjects of Karbate equipment and accessories by H. H. Frash of the National Carbon Co., and general refinery operations by G. R. Hettick of the Phillips Petroleum Co. Borger refinery. Average attendance at the three meetings was 45.

Officers for the Detroit Section for the year 1954-55 are:

Chairman .....John W. Shier
Vice-Chairman .....Joseph Adinoff
Secretary .....Douglas W. Anderson
Treasurer .....James D. Leslie
Member-at-large .....Gordon Morseth

At the dinner meeting on May 12, 1954, George Granger Brown, Treasurer of A.I.Ch.E. and Dean of The College of Engineering, University of Michigan, spoke on "The Professional Engineer and Patent Law" and discussed courtroom conduct of the engineer as an expert witness. This, says D. W. Anderson, was a joint meeting with The Michigan Society of Professional Engineers.

The April 20 meeting of the Central Ohio Section was held at the Faculty Club, The Ohio State University.

Following the dinner and business meeting, the twenty-four members present heard an address by S. L. Fawcett, chief of the engineering mechanics division, Battelle Memorial Institute. Dr. Fawcett spoke on the subject "Nuclear Energy for Power—Basic Concepts Behind the Engineering Problems," in which he described the basic principles of atomic power and showed why reactors are designed as they are. He stressed the engineering problems involved and discussed possible future trends in the development of atomic power. Edwin E. Smith reported the meeting.

According to Wayne E. McCoy, publicity chairman of the Terre Haute Section, the success of Engineers' Week in that city was due in no small measure to the combined efforts of the Terre Haute Section of A.I.Ch.E. and the Francis Vigo Chapter of the Indiana Society of Professional Engineers.

(*Continued on page* 81)

ONE DAY MEETING Report

AMERICAN INSTITUTE OF CHEMICAL ENGINEERS

Philadelphia, Pa., Spring, 1954—Philadelphia-Wilmington Local Section second annual all-day meeting virtually a sell-out to every function. . . . Unique "grassroots" feature assured that the speakers would take nothing for granted about listeners' prior knowledge. . . . Results: Successful.

DISTILLATION IN PRACTICE was spelled out in both chapter and verse by the team of experienced speakers whose papers ranged from design to operation, with a liberal seasoning of history thrown in for good measure (by A. P. Colburn, Univ. of Del.).

THE ELEMENTS OF DISTILLATION COLUMN DESIGN may be broadly broken down into the handling of vapor traffic and liquid traffic (both of which now entail well-established techniques) plus the estimation of plate efficiency, according to C. Pyle (DuPont) in his paper "Over-all Column Design from a Process Viewpoint." Pyle credits the work of the A.I.Ch.E. sponsored research program for making progress on the establishment of suitable techniques for estimating the plate efficiencies.

COSTS OF FRACTIONATING TOWERS ARE GENERALLY TOO SMALL TO WARRANT "CORNER CUTTING,"—according to R. L. Geddes (Stone & Webster Eng. Corp.) in his paper "Physical Design Features of Plate Columns." The general factors one should endeavor to provide when designing a fractionating unit are: reasonable investment cost . . . . satisfactory operating performance at normal design conditions, plus suitable efficiency over any required range of throughput capacity, ease of operation and control, practical service life, and convenient and economic maintenance.

THE CHEMICAL INDUSTRY DISTILLS RELATIVELY FEW COMPONENTS, IN CONTRAST TO THE MIXTURES HANDLED BY THE PETROLEUM INDUSTRY, according to C. H. Brooks (Sun Oil Co.) in his paper "Some Techniques in Petroleum Fractionation." This paper described the use of single towers having as many as six or more side streams and thus operated as a series stacked one on top of the other. Also the use of steam stripping, circulating "cold" oil to remove heat from vapor, flash distribution, measures to prevent oil contamination of steam condensers, and the avoidance, wherever possible, of the need for direct firing.

CONTROL OF DISTILLATION was summarized W. O'Connor (Lummus Co.) in his paper on instrumentation of distillation units. By making an example process analysis of a "polyform" unit, it was determined that considerable possibility for serious damage to the equipment existed, should the flow of feed to towers be interrupted for more than three minutes. Stability of feed was therefore considered one of the most important objectives. Because of the time lag in pneumatic control systems, a table of "target time factors" for liquid holdup systems was set up. The analysis of heat control considered all flow possibilities and heat exchange means. The final steps described have to do with instrument positioning.

HOW TO START UP A DISTILLATION UNIT, and trouble-shoot when something goes wrong was covered by C. E. Strong (Hercules Powder Co.). Startup procedure entails preparation of operating manuals, setting up test procedures, organizing and training a staff including maintenance personnel, testing all plant equipment by operating with water, displacement of the water with the actual raw material. Following the discussion of each of these items, Strong continued with case histories of actual troubles that have arisen, and the measures that were taken to correct them.

THE LARGEST USE OF VACUUM DISTILLATION is in the petroleum industry, but in smaller scale it has become an important step in the manufacture of a number of pharmaceutical, chemical, and food products, said W. A. Hall (Atlantic Refining Co.). Selection of the elements of a vacuum system was discussed, and design and operating factors pertinent to the large-scale petroleum operations, were described.

ONCE AN ENGINEER, ALWAYS AN ENGINEER was the theme of C. C. Chambers (DuPont) banquet address, who holds out little hope for escape, once the "bug" has really bitten.

TRAGIC AFTERMATH to the meeting was the sudden death of the presiding chairman, C. H. Nielsen, whose obituary appears elsewhere in this issue. We all mourn his loss. [Ed.]

ONE DAY MEETING Report

AMERICAN INSTITUTE OF CHEMICAL ENGINEERS

Newark, N. J., Spring 1954—Fifth Annual All-Day Meeting of the New Jersey Local Section drew crowd. . . . Program featured techniques old and new—plus a course in human engineering, which added up to a full day of "advanced training" for hundreds of plant men.

CALLING FOR FURTHER DEVELOPMENT OF PUMPS EQUIPPED WITH SEALING DEVICES, C. J. B. Mitchell (DuPont) reported that most process pumping problems have to do with leakage rather than hydraulics. Most familiar packingless pump is the diaphragm, which has had added to it a second diaphragm to take over temporarily in event of failure of the wetted one. . . . Electromagnetic pumps, which can be used only with liquid conductors, have been built for capacities as high as 400 gal./min. and heads of 100 ft. Helical flow induction pumps are built for high pressures and low flows, with heads as high as 260 ft. of sodium developed. Linear induction pumps are best for large flows at moderate heads. . . . "Canned rotor" pumps must be used with liquids having bearing-lubrication qualities, not viscous or abrasive materials. . . . Sonic pumps offer promise.

PRACTICAL CLASSIFICATION OF DRY-MIXING TECHNIQUES AND MACHINES was the subject of L. T. Work (consulting engineer of N. Y.), who presented the paper "Dry Mixing of Solids." He listed the following qualities as significant in achieving desired results: 1) relative amounts of materials to be handled, 2) density of components, 3) particle size, and 4) particle shape. Work continued by analyzing mixing-action first on the broad basis of batch mixers vs. continuous mixers vs. mixing systems and then according to typical examples of commercially available machines.

WHEN SOLIDS ARE TO BE MIXED WITH LIQUIDS, experience is still the best guide, according to J. L. Diltz (J. H. Day Co.), who defined a satisfactory mix as coating the inner surfaces of the particles with liquid. This is accomplished in two ways, by external physical shear or by internal dynamic shear. The first method provides direct contact between particle and foreign body such as an agitator; the second provides particle-to-particle contact, which is regarded as more valuable in practice. Diltz concluded with examples of commercially available machines.

COMPARISON OF MILLS AND HOMOGENIZERS as means for accomplishing dispersion was treated by L. H. Rees (Manton-Gaulin), who explained that wetting and shearing forces must be applied along with the dispersing forces. Ball mills exert shear pressure and mix . . . . Roller mills exert internal shear pressure as the product passes between the rolls and intensive mixing takes place. Colloid mills develop shear and pressure by rotation of the rotor in close proximity to a fixed stator. Homogenizers accomplish this by high-velocity flow between closely positioned surfaces. . . . The wide variation which exists even between models of colloid mills and other machines aids considerably in selecting the right machine for the application.

WAYS TO USE STRAIN GAUGES IN PROCESS PLANTS for weighing and for pressure and torque measurement were revealed by D. J. Jones (Ruge-DeForest). These gauges are made up of resistance wire, whose value changes as the gauge assembly (which is flexible and is cemented to the surface measured) is lengthened or shortened.

FEED A SINUSOIDAL WAVE INTO A PROCESS, and the characteristics imparted to it upon leaving provide unique and potentially interesting means of identification, study of rate processes, and use in automatic control, according to E. F. Johnson (Princeton Univ.).

WORKING WITH PEOPLE was the subject of three papers, one of which by F. F. Bradshaw (Richardson, Bellows, Henry & Co.) recognized the young engineer's problem of transition from student technologist to supervisor of people. . . . Some of the reasons why difficulties arise among people were analyzed by K. Cornell (Institute of Effective Speaking, New York). . . . "Building the Will to Work" was the title of a talk by W. V. Machaver (Johnson & Johnson), who dealt with people's wants and how these might be provided in order to bring about better cooperation and productivity.

LOCAL SECTION NEWS

(Continued from page 78)

These agencies arranged for the public window display of the Mayor's proclamation and for industrial displays of various functions of engineers. Exhibits were made by Commercial Solvents Corp. and Chas. Pfizer Co., and other local basic engineering firms were listed in the window display. Newspaper and radio publicity was not wanting either.

"Sharing" was the order of the May 10 meeting of the C.D.I.C. (Cincinnati-Dayton-Indianapolis-Columbus) Club held in Cincinnati, Ohio, at the Hotel Alms. W. L. Foy, secretary, wrote members to come prepared to share "Your experiences with us."

At the April 12 meeting Virgil Sheets of Rohm & Haas Co. gave an enlightening talk on the formation of acrylic polymers and their use as film formers in emulsion paints.

Current industrial applications of jet reactors in mining, and gas compression were described by L. J. Spillane at the April 23 meeting of the El Dorado Section held at Dewey's Steak House. Thirty-five members and guests listened attentively to Dr. Spillane, Lion Oil Co. Research Division, discuss "Jet Reactors—A New Engineering Tool." The new approaches to chemical synthesis in the petrochemical field through jet reactors was explained.

O. A. Fuchs, chairman of the Publicity Committee of the El Dorado Section, asks to be excused for his remissness in not keeping us informed each month, but he did summarize the current year's activities (Thank you, Mr. Fuchs). We note that at the March meeting T. B. Crowell, production superintendent, Copolymer Corp., Baton Rouge, La., covered the problems associated with the development of a test-tube process to full-scale commercial production.

"Hydraulics of Gas-Liquid Contacting Trays" was discussed by R. L. Huntington, professor of chemical engineering, University of Oklahoma, at the fifth meeting for 1954 of the Baton Rouge Section held on May 10 at the Bellemont Restaurant. Prior to joining the staff of the University of Oklahoma, Dr. Huntington served two years with the U. S. Chemical Warfare Service. Seventy-three members and guests attended, of which nineteen were graduating in chemical engineering from L.S.U. and were guests of the section. Thomas C. Lendrum, secretary of the section, sent in word of this meeting.

At the fourth meeting held on April 22 at Mike and Tony's, forty-five members and guests were present. As announced previously James Mair of the Goslin-Birmingham Co. was the speaker.

H.R.G.

PEOPLE

Beginning with the September, 1954, term Princeton University's School of Engineering will have a new dean in the person of Joseph Clifton Elgin, now associate dean and chairman of the department of chemical engineering. When Professor Elgin assumes his new duties he will relinquish the chairmanship of the department of chemical engineering to Professor Richard H. Wilhelm, a member of the Princeton faculty since 1934.

J. C. Elgin

With the Princeton faculty since 1929, Professor Elgin has been chairman of the department of chemical engineering since 1936. In 1939 he became associate dean, filling a newly created position in which he has assisted with the School's graduate program. A consultant to the Atomic Energy Commission and a trustee of Associated Universities, Inc., during World War II Professor Elgin served the National Defense Research Committee, War Production Board, and the Manhattan Project, Columbia University.

Professor Wilhelm, who succeeds as chairman of the department of chemical engineering, received his B.S. in engineering, his Ch.E. and his doctorate at Columbia University, the latter in 1935, after he had joined the Princeton Faculty. He has served the National Defense Research Committee operations at Princeton, and the project at Princeton for the Office of the Rubber Director. He was a consultant to the Research and Development Board, Department of Defense.

R. H. Wilhelm

Professor Wilhelm received the William H. Walker Award of A.I.Ch.E. in 1951 for his ". . . outstanding contribution to the literature of the chemical engineering field." The following year he was again honored as the recipient of the Professional Progress Award, sponsored by Celanese Corporation of America and by A.I.Ch.E.

DORR HONORED BY THE CHEMISTS' CLUB

John Van Nostrand Dorr, President of A.I.Ch.E. (1932, 1933) and founder of

the company which bears his name, was elected an Honorary Member of The Chemists' Club, New York, at the annual meeting held on May 5, 1954.

Becoming President of The Dorr Co., engineers, New York, in 1916, Dr. Dorr served until 1949 when he became chairman of the board. In his early days he served as chemist, assayer, operator and consultant in the West. In 1910 the Dorr Cyanide Machinery Co., Denver, Colo., was formed and incorporated, to be succeeded in 1916 by the Dorr Co. to market the Dorr Classifier, Thickener, and Agitator.

Dr. Dorr, D. Eng., Michigan College of Mines, claims that his urge to invent was due to his association of some two years with Thomas A. Edison in the latter's New Jersey laboratories, which also led to young Dorr's majoring in chemistry at Rutgers University.

President of the United Engineering Trustees in 1931 and trustee of his alma mater Rutgers University, Dr. Dorr has received many honors, among them membership in the Legion of Honor of the American Institute of Mining and Metallurgical Engineers in recognition of his fifty years of service as a member, and the John Scott Medal of the Franklin Institute.

CREASY HONORED BY PRESIDENT EISENHOWER

William M. Creasy, Major General, U. S. Army, formerly in command of the Army Chemical Corps, Research and Engineering Command, was recently named by President Eisenhower to head the Army Chemical Corps. A B.S. from the U. S. Military Academy and an M.S. in Chemical Engineering Practice M.I.T., he entered military service early in his career. Making the Army his life work, General Creasy has served at Leavenworth, Kan., Pine Bluff Arsenal, Pine Bluff, Ark., Pentagon in Washington, D. C., and at the Army Chemical Center, Maryland, as Commanding General.

R. A. BENZAQUIN IN NEW ROLE WITH CELANESE

With the Celanese Corporation of America since 1951 serving as a chemical engineer in the operations-control department located in the New York office, Richard A. Benzaquin has been advanced to the position of general superintendent, chemical division, plasticizer plant, Newark, N. J. Prior to his association with Celanese, Mr. Benzaquin was assistant to the Executive Secretary of the American Institute of Chemical Engineers for five years. A graduate of M.I.T. (1941), Mr. Benzaquin holds the degree of B.S. in chemical engineering. He was at one time affiliated with the Koppers Co., Inc., Pittsburgh, Pa., as a chemical engineer.

Clifford C. Furnes, director of the Cornell Aeronautical Laboratory, was appointed Chancellor of the University of Buffalo by the Council of the University at a recent meeting. The appointment will become effective Sept. 1.

A native of Indiana, Dr. Furnas holds a B.S. from Purdue (1922), a Ph.D. from the University of Michigan (1926), and an Honorary Doctor of Engineering from Purdue (1946). In 1922 he was awarded the Big 10 Conference Medal for the best combined scholastic and athletic record.

Immediately after leaving Purdue he was track coach and mathematics teacher at the Shattuck School, Faribault, Minn. This was followed by research work at the Illinois Steel Co. and graduate work at the University of Michigan. Subsequently he conducted research work on metallurgical processes at the U. S. Bureau of Mines, joined Yale University as associate professor in chemical engineering, and maintained a number of industrial consulting connections, worked for the National Defense Research Comm., and served as director of Curtiss-Wright research laboratory in Buffalo. This laboratory was given to Cornell University on Jan. 1, 1946, at which time he became executive vice-president and director of Cornell Aeronautical Laboratory.

Dr. Furnas will be the ninth chancellor of the University of Buffalo. When the university was founded in 1846, Millard Fillmore, who later became president of the United States, was its first chancellor.

Seymour Weinstein has recently become technical director of Niagara Filters division, American Machine and Metals, Inc. He was formerly central district sales manager for Niagara with headquarters in Chicago. A graduate in chemical engineering from the University of Buffalo, Mr. Weinstein previously was associated with National Aniline, division of Allied Chemical and Dye Corp., Commercial Alcohol Corp. and Ansbacher-Siegle Corp. He joined Niagara Filter in 1945.

Norman H. Callner has been appointed to the newly created position of chief project engineer of the compressed gas division, The Liquid Carbonic Corp., Chicago, Ill. His duties will include the supervision of a plant improvement program, development work and construction of new plants. Prior to his appointment, Mr. Callner, who has been with the company since 1947, had been responsible for the design, layout, purchasing, construction, and initial operation of new Liquid dry ice plants in Belleville, N. J., Philadelphia, Pa., Maracaibo and Caracas, Venezuela, and Montevideo, Uruguay.

William Alfred LaLande, Jr., manager of research and development, Pennsylvania Salt Manufacturing Co., Philadelphia, Pa., is now vice-president. Dr. LaLande joined Pennsalt in 1944 and has been directing the research and development program at Wyndmoor, Pa., since 1948. From 1927-37 he served as a member of the faculty, University of Pennsylvania, and during the following year did post-doctoral work in organic chemistry at the Swiss Federal Polytechnic Institute in Zurich. From 1938 to 1944 he was director of research and development for the Attapulgus Clay Co.

Edward M. Redding is now director of research and development, responsible for the development and operation of a complete program of scientific research and development, crown and closure division, Crown Cork & Seal Co., Inc. Prior to his affiliation with this company Dr. Redding was associated with the Aerophysics Laboratory of the North American Aviation, Inc. (1946-48), director of research of the Charles F. Kettering Foundation (1948), and in 1953 served as director for the Sharples Corp. where he directed research on, and development of, new products.

(Continued on page 87)

CLASSIFIED SECTION

Address Replies to Box Number Care of CHEMICAL ENGINEERING PROGRESS

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CHEMICAL ENGINEER—Research and development work in Main Line Philadelphia area. Technical work concerned with construction and operation of pilot plant in fields of chemistry, metallurgy, ceramics and minerals separation. Send résumé and salary required. Box 4-6.

CHEMICAL ENGINEER—Graduate with a background of experience and accomplishment. Must have some knowledge of mining and mineral refining, also mechanically resourceful to carry a project from laboratory stage in United States to full scale operation in western Canada. Must have mathematical inclination to solve complex engineering problems. Both chemical and mechanical knowledge desirable. Age about 35. Salary range $7,000—$8,000. Box 1-6.

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SITUATIONS WANTED

A.I.Ch.E. Members

CHEMICAL ENGINEER—PRODUCTION MANAGEMENT—Age 36. M.Ch.E. Twelve years' experience includes resident manager of alcohol plant; chief engineer of eight-plant organization; assistant to vice president in charge of production. Seeking responsible position in production, management or plant engineering. Box 2-6.

THREE CHEMICAL ENGINEERS—Available in August. These men have four, five and twenty-four years' experience in the development, design, and manufacture of pharmaceuticals and organic chemicals. Presently employed in Midwest. Box 3-6.

SALES—Live wire chemical engineer, bored with research and development, desires challenging opportunity in chemical or process equipment sales. Seven years' diversified experience in organic coatings, explosives, and allied chemicals. B.Ch.E. Age 29, single, personable, good appearance. Box 6-6.

CHEMICAL ENGINEER—B.S.Ch.E. Age 26, married, family. Three years' diversified experience in research and development in petroleum refining. Patents pending. Honors, Tau Beta Pi, engineer-in-training. M.S. partially complete. Desire research, development, engineering, or production. Box 7-6.

RUBBER CHEMIST-ENGINEER—Eight years of product development, equipment design, plant engineering and management. Recently directed construction of molded goods plant. B.Ch.E. plus graduate credits. Box 8-6.

INSTRUMENT ENGINEER—B.Ch.E. 1951. Age 32, family, veteran. Two years process development and plant trouble shooting—conventional and high pressure processes. One year instrumentation—system applications. Desire challenging position leading to supervision. Box 9-6.

TOP MAN in graduating class. B.Ch.E. 1950. Four years' process design and development experience mostly in nuclear industry. Single, 26, occupational draft deferment. Industrious, personable, excellent record and references. Desire challenging, promising position. Box 10-6.

CHEMICAL ENGINEER—Age 32. B.S., P.E. Nine years in the manufacture of organic chemicals and plastics including production supervision, process improvement and development. Desire responsible position in production management or development. Box 11-6.

AVAILABLE—Twelve years of experience in production, process development, and process design. Desire responsible production and/or engineering position with small aggressive chemical company in the South. Ga., N. C., or S. C. preferred. Résumé furnished on request. Box 12-6.

CHEMICAL ENGINEER—B.Ch.E. University of Cincinnati. Seek position in production or engineering with opportunity to develop administrative and technical abilities. Two years' technical and production experience in chemical industry. Age 26, married. Box 13-6.

PRODUCTION—SUPERVISION—CHEMICAL ENGINEER—Age 30. M.S.Ch.E. Four years' experience in production supervision and staff engineering. Presently in charge of continuous process chemical plant. Special qualifications in processing metallic sodium and vacuum distillation. Desire responsible position in production or process development. Western United States. Box 14-6.

CHEMICAL ENGINEER—B.S.Ch.E. 1950. Age 32, family. Four years' experience in research and development fatty acids and derivatives. Desire to relocate in Southwest desert region. Box 15-6.

CHEMICAL ENGINEER—Twelve years' experience in application, design, and plant layout of processing equipment. Particularly strong on problems involving high temperature heating systems and allied equipment. Some administrative experience. Considerable client contact and sales experience. Desire position leading to administrative responsibility. Age 37. Available with notice. Box 16-6.

CHEMICAL ENGINEER — B.S.Ch.E., Lehigh University. Diversified experience in chemical plant operation, production supervision, engineering and administration. Sales or administrative position with small company in Philadelphia area is desired. Age 37, family. Box 17-6.

PLANT ENGINEER—B.S.Ch.E. 1939. Experienced design, maintenance, construction, production in heavy chemicals and fermentation. Desire responsible position requiring full use of this experience. Location secondary to opportunity for advancement. Box 18-6.

Nonmembers

CHEMICAL ENGINEER — Process development and pilot plant design and operation experience in the organic chemical field. B.Ch.E. 1951. Available immediately. Box 19-6.

SUPERVISOR—Six years' production supervision experience chemical plants, five years' safety field (2½ years insurance, 2½ years chemicals). Present position safety, fire, and medical supervisor. 38 years old, degree, production management and business administration. Seek progressive company and opportunity. Box 20-6.

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PEOPLE

(*Continued from page* 85)

H. A. Persyn is now serving as superintendent of the fine chemicals plant of Reilly Tar & Chemical Corp., He joined the company in 1936 and was formerly superintendent of the corporation's Newark, N. J., plant. More recently he has been in charge of the Indianapolis Refinery.

Richard Laster, formerly assistant laboratory director at General Foods Central Laboratories in Hoboken, N. J., has been appointed research manager for the company's Walter Baker division. He joined General Foods in 1944 as a junior technologist at Central Laboratories.

As announced in C.E.P. (May, 1954, page 96) **Kenneth S. Valentine** has set up his own business as manufacturers' representative, and it can be stated now that initially he will represent in the New York district, The Manton-Gaulin Co., of Everett, Mass., makers of homogenizers and high pressure pumps. In the New York and Philadelphia areas he will handle products of The Stevenson Co., Dayton and Wellsville, Ohio, manufacturers of ball and pebble mills, liquid and dry mixers, and other chemical process equipment.

Ralph A. Troupe was recently appointed research professor of chemical engineering at Northeastern University. He will direct an industry-sponsored research program in chemical engineering and allied fields. Dr. Troupe was formerly technical superintendent of the Akron plant of the Goodyear Synthetic Rubber Corp. He has also taught at the University of Texas and the University of Louisville.

Summers Fertilizer Co., Baltimore, Md., recently announced the appointment of **C. LeRoy Carpenter** as vice-president and technical director of the company and its affiliate, Northern Chemical Industries, Inc. Dr. Carpenter goes to Summers following two years of chemical development work with the Grace organization. Prior to his association with Grace, he had several years' experience with Colgate-Palmolive-Peet Co. and Standard Oil Company of New Jersey. During the war he received the Award of Merit for his contribution toward the development of atomic energy for the government.

Ernest W. Neben, formerly chief process engineer of the Pfaudler Co., is now manager of the firm's chemical equipment division. As an engineer for The M. W. Kellogg Co., New York, he worked on high temperatures and high pressure problems for the petroleum and petrochemical industries for five years. He then joined the Colgate-Palmolive-Peet Co. of New Jersey in an engineering capacity, leaving in 1949 to join Pfaudler.

The appointment of **M. T. McCants** as plant manager for the new refinery to be constructed by the Great Northern Oil Co. at Pine Bend, Minn., was recently announced. He goes to this position from Corpus Christi, Tex., where he has been associated with the Great Southern Chemical Corp. as general plant superintendent since 1951. Previously, he was process and project engineer for the Fluor Corp., Ltd., serving in Montreal, Canada, and Los Angeles, Calif., and with Humble refinery, Baytown, Tex.

It was recently announced that **J. P. Ekberg, Jr.**, has been appointed assistant to the president of Monsanto Chemical Co. and secretary of the executive and finance committees. He joined the company in 1940 in the analytical laboratories and in 1942 was made assistant production supervisor. In 1946 he became a sales engineer for the organic chemicals division, and in 1951 assistant manager of petroleum chemicals sales. Since 1952, he has been technical representative in the Washington office.

Food Machinery & Chemical Corp. has announced the appointment of **A. G. Aitchison** as manager, development department, Westvaco mineral products division. Mr. Aitchison joined Westvaco in 1935.

Necrology

Chemical Engineering Progress has recently heard of the death of the following members of A.I.Ch.E.: Raymond C. Briant, William E. Stewart, Herbert J. Hershman and C. H. Nielsen.

Dr. Briant was chief research scientist at Oak Ridge National Laboratory. At one time he was associated with the Mellon Institute of Industrial Research in Pittsburgh. He was 52 years old.

Mr. Stewart, who had received a B.S. from Purdue University in 1951, was associated with Griscom-Russell Co., Massillon, Ohio.

Mr. Hershman was a chemical engineer with Carbide & Carbon Chemicals Co., Oak Ridge, Tenn. He received a B.S. in chemical engineering from Northeastern University, Boston, Mass., and was at one time affiliated with the Kellex Corp.

Charles H. Nielsen, a research supervisor in the chemical engineering section of the Engineering Research Laboratory, Du Pont Co., died suddenly on May 2, 1954, in the Delaware Hospital in Wilmington, Del. A graduate of Nebraska University and holding a master's degree from Rutgers University, Nielsen joined Du Pont in 1936 as a research chemist with the Organic Chemicals Department at the Jackson Laboratory of the Chambers Works. Subsequently he was in charge of the operation of neoprene, transferred to the neoprene plant at Louisville, Ky., entered development work with the engineering department, was assigned to the Dev. Eng., Experimental Station. He was active in the affairs of the Philadelphia - Wilmington Section of A.I.Ch.E., contributing to the work of the Program Committee for that Section's first all-day meeting in 1953 and in 1954.

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A.I.Ch.E. News And Notes

Springfield scheduled no Council meeting, but the Executive Committee smoothly ran through interim business.

All actions are subject to final O.K. by Council, usually through approval of the Executive Committee minutes.

Henry S. Meyers was appointed counselor of the City College Student Chapter, succeeding A. X. Schmidt. Merk Hobson was approved as the counselor of the Student Chapter of U. of Nebraska, replacing H. T. Bates.

Carl Westphal will be one of the Institute representatives at the UPADI meeting this August in Sao Paulo, Brazil.

All above was routine, but on several items discussion was prolonged.

Dues structure for the new grade of Associate, which, if Constitution Amendment is accepted, replaces Junior & the present Associate, has been the subject of a long discussion & correspondence on the part of most Council members.

A completely new look at Institute dues and entrance fees is underway.

Executive Committee finally turned the study of all suggestions over to Headquarters for evaluation and collection of data.

In another action Executive recommended to Council approval of expenditure to alter space for new offices.

Move to new headquarters is expected around the middle of July. New address will be 25 West 45th Street, third floor.

Suggestions are frequently received from members or sections on modifications of Institute procedures. These fall into two categories. If they affect bylaws, Council can act quickly since changing these requires only Council approval.

Constitutional changes are something else again. Usually they are referred to the proper committee for study and suggestions.

This month two such ideas came before Executive Committee.

One from the South Texas Section concerned the election of officers on a regional basis, the other suggested the creation of several vice-presidential posts to help the President of the Institute with the present load of travel, committee liaison, etc.

Both were referred to the Committee on the Future of the Institute now under the direction of Henry Rushton. Each of these ideas had been suggested before, & will again be considered.

A.I.Ch.E. will be one of the sponsors of the Midwestern conferences on Fluid Mechanics & Solid Mechanics to be held September 8-10 at Purdue University.

Vital committee work is an important Institute tool. One of quietest, yet a most valuable committee of the Institute is the Education and Accrediting Committee.

Basic objective is to maintain & improve education in chemical engineering throughout the country.

Through discussion, symposia, & personal contact, the committee makes available to all educational institutions basic requirements of a sound curriculum in chemical engineering.

Further it also sits in judgment in determining which colleges meet the standards. This is the "accrediting" function.

Cooperation with E.C.P.D. is complete; all official communications are handled through it.

First inspection of an engineering curriculum in cooperation with the Middle States Association & E.C.P.D. was made in 1943.

Forty actions were taken last year by the committee; five were inspections of curricula not previously accredited (resulting in one new addition to the list) plus twenty re-inspections of previously accredited schools.

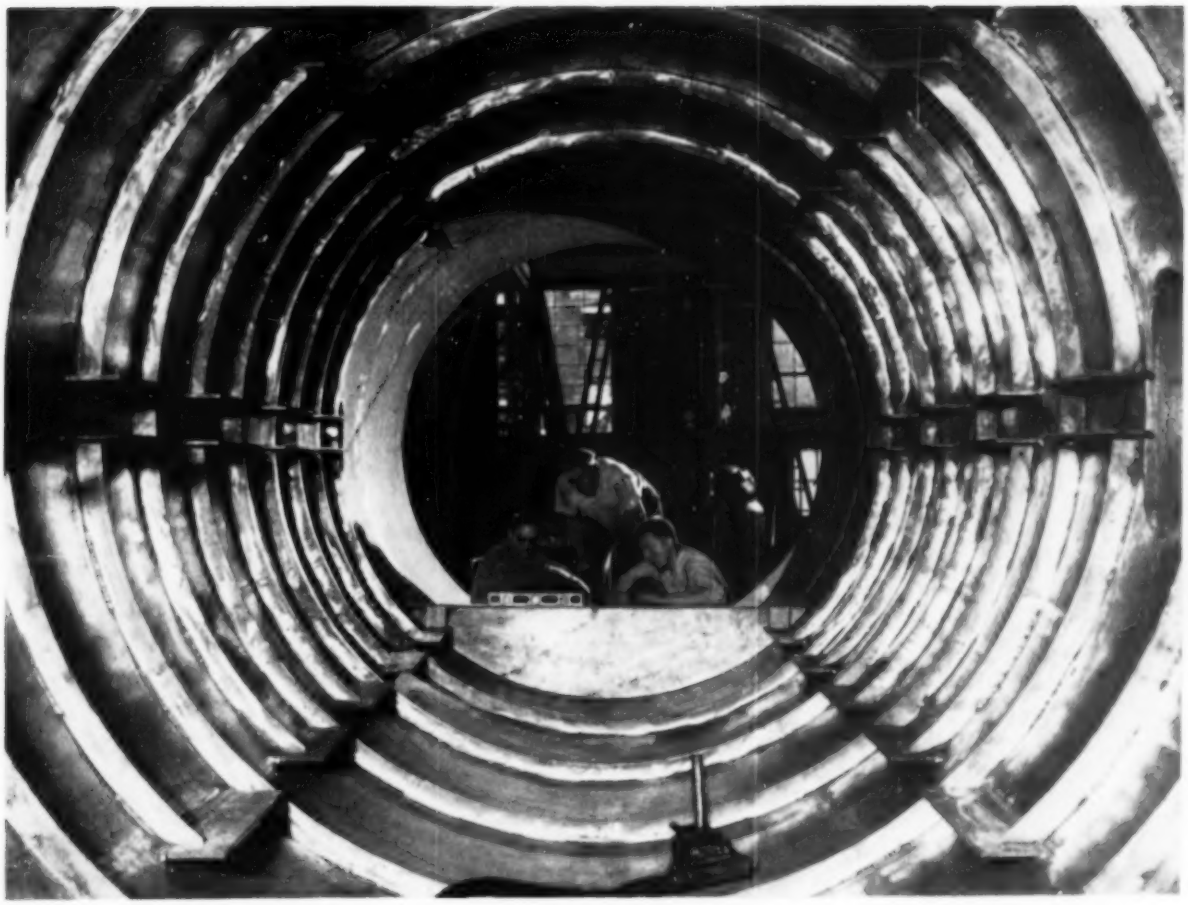
There are eighty accredited courses in the United States, & in 1954 thirty-six will be inspected.

United States is broken up into seven different regions - each with an inspector plus four members at large.

Considerable time is spent by committee members on each inspection. Reports are submitted to the complete committee for a review.

For the previous five years the committee was under the direction of George Granger Brown of the University of Michigan. This year it passed to R. A. Morgen, formerly of the University of Florida and now with the National Science Foundation.

F.J.V.A.



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It's the inside story of process equipment fabrication that the engineer and buyer in these times cannot afford to overlook. It includes proven methods of manufacture, special techniques and machinery, rigid inspection and testing—all found in Vulcan Manufacturing.

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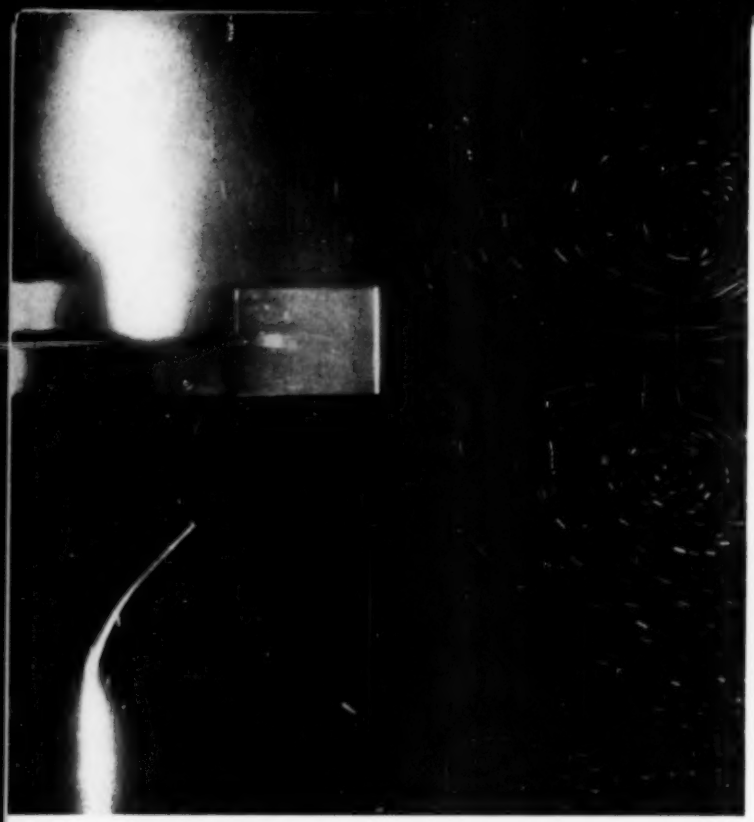

STREAK PHOTO shows how fluid flow from impeller produces fluid shear (turbulent areas of pattern). You can harness flow and shear, control them, make them work harder. Doing so results often in 100% more mixing efficiency.

ACCURATE MIXER SCALE-UP results from thousands of runs in pilot plant equipment such as this unit for heat transfer study.

TOP ENTERING mixers, turbine and paddle types, are supplied in sizes from 1 to 500 HP.

SIDE ENTERING mixers, for large tanks, are available in sizes from 1 to 25 HP.

PORTABLE mixers, electric or air driven, are supplied in 30 models, ⅛ to 3 HP.

How to control fluid flow for *RAPID, UNIFORM MIXING*

You can do many fluid mixing jobs, quickly and well, with the simple mixer flow pattern shown here. You can use it to:

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move heat into or out of a vessel

blend several liquids to smooth uniformity

get tremendous contact area in a gas-liquid or liquid-liquid system.

Fluid flow is controlled mainly by varying the diameter of the impeller.

Fluid *shear* (a useful condition in some processes, less desirable in others) is largely the result of impeller *speed*.

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GET THE FACTS QUICKLY. For 30 years, we've helped process men mix fluids for maximum results. You may save weeks of research and pilot plant time by checking with us. We're fully equipped to give you the right research answer to any fluid mixing problem—quickly, and without cost to you.

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